DESIGNING A EVIDENCE-BASED DESIGN TOOL

- CHALLENGING THE PRACTICE OF HEALTH CARE ARCHITECTURE AND EXPLORING IT THROUGH THE DEVELOPMENT OF A PARAMETRIC DESIGN TOOL

MASTER THESIS, DIGITAL DESIGN

MA4-DD1

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1.1 Title sheet

Information
4th semester MA, Digital Design
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Title
Optimized design processes in Health Care Architecture

Theme
The development of parametric analysis tools in architectural design of health care projects.

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Group
AD4-DD1

Main supervisor
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Consultant
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Main product report

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1.2 Abstract Danish

Formålet med dette projekt var at undersøge en arkitektvirksomheds praktiske anvendelse af evidensbaseret design for herigennem at kunne opstille en metode ved brug af programmet Rhinoceros 3D med plugin Grasshopper for 1) at styrke integreringen af evidensbaseret design viden i de tidlige skitsefaser og 2) at bedømme graden af opfyldelsen af de nedsatte evidensbaserede design kriterier med fokus på patientsikkerhed i et design forslag.

Studierne var baserede på både kvantitative og kvalitative metoder. I projektet blev kvalitative interviews med ansatte arkitekter samt personale inden for sundhedsvæsenet gennemført. Dette for at analysere relationerne mellem evidensbaserede design koncepter i et designforslag, og den registrerede effekt af dele af det færdige byggeri.

For at identificere potentialer, behov og krav til en mulig metode blev scenariemodeller opstillet i samarbejde med arkitekterne. Projektet anvendte parametrisk 2D/3D CAD modellering til at skabe metode- og værktøjsprototyper, som eksemplificering af de operationer og funktioner metoden skulle indeholde. For at evaluere prototypernes potentialer blev undersøgelser med fokus på kognitiv gennemgang af værktøjerne udført med arkitekterne. For at uddrage bedømmelsesinformationer blev kvantitative spørgeskemaer udarbejdet og brugt til den videre udvikling af prototyperne. Projektet har anvendt 2 separate undersøgelser med 9 individuelle respondenter. I alt er 18 spørgeskemaer blevet anvendt hvoraf 10 spørgeskemaer er blevet besvaret og brugt.

Resultaterne af studierne var, at et softwarebaseret designværktøj besidder signifikante potentialer, og at arkitekterne bifalder projektets prototyper som bud på en brugbar og værdifuld tilgang til 1) at integrere og bruge evidensbaseret information og 2) at optimere designprocesser og sundhedsfaciliteters umiddelbare effekt. Resultaterne viste at en videre udvikling af dette projekt bør fokusere på informationsstrukturering som fundament for parametrisk design. Endvidere indikerede resultaterne, at prototypedesign bør udvikles til implementering i Building Information Modelling systemer.

1.3 Abstract

THE PURPOSE OF this study was to investigate the field of evidence-based design used in architectural design practice to be able to propose a method using the software application Rhinoceros 3D with plugin Grasshopper to 1) enhance the integration of evidence based design knowledge in the early sketching phase and 2) to assess fulfilment of evidence based design criterion regarding patient safety in a design proposal.

The study was based on both quantitative and qualitative methods. Throughout this study qualitative interviews with architectural employees and healthcare personnel were conducted. This to examine the relations between evidence-based design concepts in the design proposal, with the output performance of the built facilities. Scenario models were designed in correlation with architects to specify potentials, needs and demands regarding the development of the method. The study used parametric 2D/3D CAD modelling to create tool prototypes to exemplify the operations and functions that a future method might hold. To evaluate the prototype potentials, surveys with the architects were conducted with focus on a cognitive walkthrough of the tools. To retrieve specific information of evaluative character, quantitative questionnaires have been administered and used in development of the tools. The project has used results from 2 surveys with 9 individual respondents. A total of 18 questionnaires have been sent out where 10 questionnaires were answered.

The results of the study were that the potentials of a software based design tool are significant and that architects recon the project prototypes as a meaningful and valuable approach for 1) integrating and using evidence-based information and 2) optimising design processes and health care facility performances. It was found that future development of this project should focus on information structuring as foundation of parametric design. The results further indicated that prototype tool design should be integrated in Building Information Modelling systems.

1.4 Preface

This thesis is written as a knowledge contribution to the emerging field of architectural health care and evidence-based design practice by exploring cross-disciplinary use of software applications.

1.5 Acknowledgements

The author would like to thank the following individuals and groups for their investments, making this project a realisation.

Gudrun Østergaard, head of the health care architectural department at Friis & Moltke, Aalborg for sharing the knowledge of the department and participate in the prototype surveys. Pernille Weiss Terkildsen, Director of ArchiMed for sharing her network and experience on evidence based design. Heine Overby, Manager of Production and Buildings, Region North for pinpointing patient safety on a practical level, the staff at Aalborg Sygehus for their patience and participation during interviews. The passionate students of health care architecture at the Architecture programme, Spring 2010, Architecture, Design and Media technology, Aalborg University for their time spent on tests and trials during the designs of the prototypes. Søren Bolvig Poulsen, Assistant Professor, Industrial Design at Architecture, Design and Media technology, Aalborg University for counselling and critique during the project and Michael Mullins, Associate Professor, Architectural Design at Architecture, Design and Media technology for his help in navigating within the fields of study.

1.6 Reading Instructions

THE PROJECT REPORT is the documentation of a thesis project at Architecture, Design and Media technology, Digital Design, 2010 concerning investigations of evidence based design tools for health care building projects.

Two parts constitute the report; 1) a design documentation report and 2) a design process appendix posing elaborations on various design analysis and choices made through out the project.
Embedded on the backside of the cover of the report is a CD-ROM with the necessary files to access the project contents.

The design report consists of chapters of informal definitions and analysis, tool design and experiments ending with a presentation and evaluation of the end product of design. Each chapter contains sections elaborating the content of the topic displayed with a shared colour tone.

The appendixes follows the design report index colour tone and contain selected themes and topics from where crucial decisions have been made, this as supplementary and supportive reading regarding the tool design and its abilities.

The report is to be read in a chronological way. It is recommended to use the design appendix as a supplement to the design phase of the project.

External references will be specified by the Harvard method like below:
Books..[author, year, page number]
Papers..[author, year, page number]
Articles..[author, year, page number]
Internet links..[title, short web url, date]

Due to relations between content of the individual chapters of the report internal references will be used to support the understanding of the report. These are specified like below
Internal reference...[section name, page number]

References to the files located on the attached CD-ROM are specified like below:
CD references...[CD, folder name, file name]

INTRODUCTION

2.1 Background

THE PHYSICAL HEALTH condition of the overall Danish population is decreasing. Since 1987 the number of obese citizens in the Danish population have increased by 75 %. Following the tendency of obesity is an amount of various health related sicknesses and disorders, e.g. chronic diabetes, heart failures and extensive surgery. [http://www.dr.dk/Nyheder/Indland/2007/09/16/044621.htm, 03.03.2010]

This tendency is common for many western European countries, where increase in living standards, economic rise and excessive consumerism have been present the last two decades. [Ulrich, R., 2010, Interview A]

As a consequence the present Danish government have approved a national health care strategy, building new improved regional super hospitals with larger capacity levels and improved treatment methods. [http://www.sum.dk/Om_ministeriet/Strategier_og_politiker.aspx, 03.03.2010]

Health care strategy; Super hospitals

The new health care super size project, DNU, Det Nye Universitetshospital (The New University Hospital) located at Skejby, Aarhus in the eastern part of Jutland, is to represent the future of Danish health care, by integrating the latest technologies and the best possible experience within the different fields of health care and medical treatment. [http://www.godtsygehusbyggeri.dk/Nyheder/Region%20Midtjylland/Patient%20i%20fremtidens%20hospital.aspx, 28.02.2010]

Physical projects like these hold many visions and requirements regarding topics such as function, space, facility, utility, law, staff and safety.

The topic under which the physical form and organisation is explored is commonly referred to as Health Care Architecture.

Following the political visions of high quality treatment and low cost performance such architectural building projects demand increased systematisation, organisation and structuring of the building design process to ensure most benefit at lowest possible cost through out the project.

[http://www.godtsygehusbyggeri.dk/Nyheder/Danske%20Regioner/-OE-konomisk%20styring%20af%20st-oe-rre%20anl-ae-gsprojekter.aspx, 28.02.2010]

Information and guidelines

One of the key stakeholders of this process is that of the architectural company. Weaving all the demands and goals into a reliable architectural proposal require that the architects can call upon valid experience from all professions engaged in the project since every decision made have impact on the performance of the project. To possess the overview of the entire building project, whether it is a small scale or a super scale health care project is a complex matter. [Terkildsen, P. W., 2010, Interview 08.01.2010]

Different measures have been developed in order to create a seamingless flow and distribution of evident information. Lists of different guidelines connecting certain aspects of health care to physical arrangements are available from organisations and publishers worldwide. But different authors have different preferences and interpret data and information in different ways. The decision maker will have to ask questions all through out the design process. What kind of information is evident? Is some data more evident than other? If so, what are the factors that cause this, and is it relevant for this specific task? And what about areas with poor or no published evidence? And how is a simple guideline converted into form organisations and rules? And how can the experience be translated back into supporting evident material?

Very few professionals, being either architects or medical researchers dare to further the experienced guidelines into publishing sets of simple design rules because of the possibility to be proven wrong by research results waiting around the corner. [Ulrich, R., 2010, Interview 16.03.2010]

For many years other professions and industries have been developing and embedding innovative technological instruments to calculate or simulate performance and form. By using optimisation and rationalisation algorithms upon a structure better design can often be achieved. [Kolaveric et al.]

Optimisation technologies in the design process

If to apply such concepts of innovative use of techniques and technologies in design of health care architecture what is then the input and the output and how is this to be measured and assessed? If applications are developed how to ensure that the output data is relevant and sufficient enough for valuable interpretation followed by decision-making?

Working with architectural design of health care facilities is a process where the architect has to navigate between stakeholders' often sub-optimised areas of focus, the overall design programme and own architectural visions. The web of relations and connections is multiple and complex. Dealing with physical space, subjective interpretations and the concept of sickness and health, there is little chance that definitive rules and responses can be derived to create a check list of parameters and factors to follow to create universal high quality health care architecture.

Explorations of this thesis

In this context, by exploring the fields of architecture, evidence based design and software technologies this thesis seeks to develop a method of approach that can provide information and evidence to the design process as a way to meet demands and criteria defined in the building program. By doing so architects will have a way to receive information and literally document and prove their architectural evidence-based design concepts. As a benefit stakeholders of the process will have an assessment of the fulfilment of embedded evidence-based design criteria to enhance specific building facilities and the levels of health care quality.

2.2 Thesis frame

Problem field

The field in which the thesis operates is architectural practice and research within optimization of contemporary design processes in hospital design with a focus on the role of the architect and how to implement the many facetted factors, parameters, standards and needs from the parties involved.

Experience and studies show that there is a present issue involved around the implementation and assessment of evidence based design parameters in hospital design [Ulrich et. al. 2006].

The studies of this thesis will explore how to digitally transcend the sum of evidence-based input parameters into a digital strategy for systemization. The offset is development of a software based assessment and evaluation method of design criteria.

Initial problem statement

"How to design a digital parametric tool for evaluation of evidence based knowledge- and design parameters in architectural health care projects?"

2.3 Purpose

The purpose of this thesis is to prove that a potential product will be beneficial in matters of optimization, structuring and guidance within the architectural practice of health care architecture.

Further that the thesis prove the significance of designers of digital specialization within the interdisciplinary field of architectural study and practice.

Furthermore it is the vision that the thesis will establish the foundation of future research at the Institute of Architecture and Design, Aalborg University.

The following learning criteria are formulated on behalf of the taxonomy of Bloom as described in the master education curriculum of Architecture, Design and Media technology. [http://www.studieweb.aod.aau.dk/generelle+regler/ma+studieordning]

Learning criteria

+ To understand relevant design theory and methodology and discuss this in the context of design processes in health care projects.

+ To understand the subjects Evidence Based Design and apply this knowledge in the design of the evaluation prototypes.

+ To be able to apply previous experience and technologies solving the parametric tasks in this thesis.

+ To integrate the right technical aspects within digital design in the context of health care design.

+ To work with empirical data and surveys in a scientific relevant way as a foundation of the analysis of the problem and development of the prototypes.

+ To analyse key aspects of the architectural design process in order to be able to map a general hospital design process as a foundation for later development of prototypes.

+ To evaluate and reflect upon the relevance of the prototypes in order to map the directions of a coherent digital EBD evaluation tool

Project goals

+ To create prototypes that are relevant and functional in matters of evidence based design.

+ To create prototypes that has the potential to improve patient safety and healing in health care projects.

+ To create prototypes for a tool that is attractive to future users and has a potential market.

2.4 Limitations

Parameters and factors

The following is the delimitation areas in the work with the development of the evaluation tools.

Architectural areas

Subjects such as aesthetic assessments, value of perception of form or related subjective architectural evaluations will not be a part of this thesis. The assessment will focus on the performance of the functions designed within the building projects.

Medical areas

The project is limited from analysis of medical subjects at molecular or bio-physical/chemical levels during the studies of patient safety and hygiene.

Parametric areas

The project is limited from testing and developing other parametrical software than Rhino and Grasshopper in any technological matter. Other software will be introduced as a part of the overall palette of available choices.

Evidence based design

The thesis will focus on Patient Safety and Patient Healing. Since many of the parameters are co-related and interlinked some overlaps between evidence-based concepts might occur, but other than that the thesis is limited from dealing with other subjects than the above mentioned.

2.5 Prerequisites

The prototype application design merge fields of architecture and design with new technologies, contemplating previous experience and new knowledge of process and product design.

The technical offset of this thesis is the creation of definitions and scripts (small tools within the application) of associative, parametric driven character, using the 3D modelling software Rhinoceros 3D, and the parametric plug in software Grasshopper.

This is the foundation of the technologies used to obtain the goal of the thesis, but other technological and theoretical approaches will be elaborated in the following section as to create a more elaborate picture of the subjects of the thesis.

2.6 Audience

The thesis is directed towards the audience of architects, designers, researchers, decisions makers, consultants and professionals with interest in the field of applied evidence based design in health care building design.

2.7 List of definitions

The following definitions are terms and topic frequently used in the thesis.

Software design

PARAMETER: A single value or factor that is part of the definition of an object, e.g. height is a parameter controlling the building objects geometry.

PARAMETRIC: A concept of how an object is defined and altered in 3D modelling; e.g. the length of a building x, width y and height z, is defined and controlled by changeable parameters

ASSOCIATIVE MODELLING: The modelling of objects, whose individual parameters are changeable and interrelated (associated) so that local changes has global effect, e.g. changing the length parameter of a window frame automatically alters the parameter of the window glass surface.

PARAMETRIC MODELLING: The modelling of objects by defining the parameters individually.

SCRIPT: A string of written text code that carries out an computational operation.

SOFTWARE APPLICATION: A collection of written codes that together perform various actions.

SYSTEM DESIGN: A topic on software engineering describing the phases of design when designing system of software.

EVALUATIVE: An ability to perform an evaluation of specific elements; e.g. the script is based on evaluative computation meaning that the computation within the script is carried out to evaluate the given state of an element.

GEOMETRICAL: An object that is defined in virtual Euclidian space e.g. the virtual representation of physical objects dimensions in space.

GEOMETRIC MODELLING: Modelling of geometry in virtual 3d space using software application e.g. Rhinoceros, 3D studio Max.

IMPACT: The following effect an object or concept have, specific to the topic in question, e.g. the impact of the building on the quality of care.

Health care design

BUILDING DESIGN: The design of a buildings functions and facilities with weight on technical and organisational aspects (opposed to aesthetic and humanistic)

PERFORMANCE: The output or effect that is the result of an object action or function

HEALTH CARE ARCHITECTURE: Architectural objects e.g. buildings and facilities, designed for health care purposes.

HEALTH CARE QUALITY: A statement derived from a positive perceived or measured value of an outcome in the field of health care. The value is measured on how well specific criteria are met. E.g. the number of infections is reduced as a result of washing bed sheets on temperature above 84 degrees. Low number of infections, better health care procedure, more safe for patients, improved quality of health care operations.

ACCREDITATION: Assessment by giving grade credits based on evaluation of criteria fulfilment.

PATIENT SAFETY: The safety relations and levels of the environment surrounding a patient undergoing treatment in a health care facility.

Evidence based design

EVIDENCE: Research material that is reviewed proving a given hypothesis e.g. a selection of articles support a statement or rule for relations between location of sinks in patient rooms and aerosol bacterial infections.

EVIDENCE BASED DESIGN, EBD: Design based on choice and decisions founded upon valid and reliable (evident) research knowledge.

BEST PRACTICE: the selection of a work method, found effective and valued through experience within the field.

RESEARCH LITERATURE: Valid and reliable data, either peer- reviewed publications, articles and books.

EVIDENCE BASED DESIGN DATA: the factorial results and stated conclusions derived from tests and experiments conducted within a field or topic.

GUIDELINES: Indications or suggested rules to be followed in design, e.g. guidelines for the location of doors derived by best practice or evidence.

Definitions or contextual constellations of words with other meaning from the above listed will be explained in the thesis.

List of acronyms

2D/3D: Two/three dimensional

BIM: Building Information Modelling

CAD: Computer Aided Design

CAM: Computer Aided Manufacturing

DDKM: Den Danske Kvalitets Model (The Danish Method of Quality)

HA: Healing Architecture (Danish; Helende Arkitektur)

DNU: The New University Hospital (Det Nye Universitetshospital)

EBD: Evidence-Based Design

EDAC: Evidence-Based Design Accreditation & Certification

EDPM: Evidence-Based Design Process Model

GGHC: Green Guide for Health Care

GUI: Graphical User Interface

HEW: Healing Environmental Wheel

ICD: Inter Connection Density (number)

RAD: Rapid Application Design

Rhino: Rhinoceros 3D

SDK: Software Development Kit

TDC: The Digital Construction (Det Digitale Byggeri)

2.8 Methodology

As foundation of the thesis a variety of methodologies are used in the different project phases.

The methods support the structure and development of the project to create convergence between the fields of study and design of product.

Preparatory work

The chosen methods that the studies, hypothesis and synthesis are based upon are that of the Integrated Design Process Model by Mary-Ann Knudstrup [2003c] and The Design Research Triangle by Daniel Fallman [2005]. A thorough description of the intended use of the methods is found in [Methodologies p. XXX] of the report.

Concepts and backgrounds are investigated through literature and on-line media, observations and interviews. Method of observations and interviews is described in the end of this section.

Design requirements

Computer-Supported Cooperative Work

The method of Computer-Supported Cooperative work is used to unfold exploration of Strategic planning, Human-Computer Interaction and Software engineering, topics found relevant for the thesis. [Caroll, J.M. & Go K., 2004, p.52] Brown [1999].

It is a method where focus is on practice and work-oriented design research in the development of applications and systems. It is a view that contemplates the more abstract, social and organisational work aspects of user and company practice as opposed to more traditional software engineering with emphasis on physical concrete artefacts in procedures and tasks [Caroll, J.M. & Go K., 2004, p.52].

Context, User, Task, Technology

The project investigations uncover design aspects around four main topics: 1) context, 2) User, 3) Task and 4) Technology. [Galletta & Zang, 2006] Investigations are made to map the present practice in architectural health care design with future development scenarios. The purpose is to use the information in prototype development and overlap between the main four topics will occur.

Scenarios based design

To gather the information needed to specify the design requirements of the project the method of scenario-based design is used to unfold the present and the possible future demands and needs regarding the system design.

Based on studies and interviews, scenarios, either narrative in text, visual media representation or work-oriented user cases is used to iteratively explore fields and make relevant design choices. The list of interviews and fields of focus is located in the Appendix section XX.

The progression of explorations made to uncover relevant topics is reflected in the diagram below.

The three circles indicate the study fields mutual relationship, which is related to the design choices tangibility in the process, going from broad and low to specific and high.

The design phase starts with strategic planning, here working with possible scenarios of future tasks and tendencies of practice and context, a field of low tangibility regarding the system design requirements. A shift is done into the human-computer interaction, HCI field with focus on scenario studies of previous and present user practice and work routines and is ended with design in software engineering exploring the tangible tool prototypes of parts of a proposed system model.

Prototype experiments are made to supplement some of the lesser tangible design matters and support the chronological progression of the project.

The scenario-based design model focus on architectural practice in health care design, with EBD as main focus under which the architect is considered primary user and the architectural practice as immediate design context.

The scenarios are tested by selected architects through a survey (survey 01) and are described in [Methodologies, p. XXX].

Design and implementation

Prototyping is used as a method to iteratively develop tool functions as the design exploration progresses. Iterative prototyping is known in the field of rapid application design.

During each design phase, to meet specific user requirements, relational models are developed as separated parts of a whole system. [Beynon-Davies, P., 1998] Prototypes are developed when basic functions are explored, small scripts to test and develop head of larger prototypes. These initial prototype samples are used in tool scenarios of the performance of the system. [Caroll, J.M. & Go K., 2004]

Prototypes are developed based on studies and selected system requirements. The prototypes display some of the basic functions and operations needed for later development.

The prototypes are tested through a survey (survey02) to test the ability of the prototypes to bridge evidence based design information with design tasks. The benefit is assumed through a questionnaire.

Data acquisition

Survey02 is used to test the design of the prototypes. The data and feedback from the survey is used to evaluate on the immediate effect during and post a design task.

A questionnaire is introduced as to evaluate the prototypes.

The prototype evaluation questionnaire is used to retrieve feedback data upon the design possibilities and issues of the prototypes and the software behind it.

Based on this output evaluation of the project criteria and goals is made.

Evaluation

Evaluation of the thesis is done by evaluation of the feedback from survey02 and the initial goals of the project. Reference to the study methods is used to evaluate the progression of the project.

Triangulation of quantitative and qualitative approaches

The following is an elaboration of how the various methods of observations, interviews and surveys have been carried out in the project.

The results of analysis and investigations are obtained through various disciplines during the project. The combination of methodologies of qualitative and quantitative character forms a more holistic contextual overview that singular methods might not illuminate [Jick 1979, p. 601].

Interview

As part of the investigations of the initial project phase a number of interviews are conducted to enrich and expand the topics and fields of analysis.

References to the interviews are found in the appertaining sections.

The interviews are built and processed by the following structure:

+ Description of topic and interviewee

+ Purpose of the interview

+ Specific areas in question

+ Conclusions

The interviews are available in recording in the attached CD. Only statements directly used in the thesis have been transcribed.

Observation

As part of the analysis of architectural design practice, observations of the design workflow using software at a workstation at Friis & Moltke architects have been used. The structure is 1) Setup 2) Observation 3) Evaluation.

Surveys

As the product part of the project evolves two surveys are conducted. The surveys serve the purpose of evaluation and exploration at specific points in the overall project period.

The methods used in the surveys are of both qualitative and quantitative nature and will be treated as part of a triangulation of results to conceive the best possible decisions in the project. [Jick 1979, p. 601]

Survey

Survey 01 is introduced in the chapter [Tool Scenarios, pXXX] as a means of concatenating the strings of choices laid out by prior investigations. It introduces the concept of the tool design and elements to a selected group of individuals. The critique is used as foundation of the development of the tool.

The survey consists of four phases: 1) product presentation, 2) discussion session, 3) questionnaire and 4) evaluation. The survey provides the project with both knowledge

and data specific to topics of importance prior to the technical development of tool prototypes.
Survey 02 [Evaluation, p. XX]
Survey 02 is introduced as evaluation of the usage and functionality of the tool prototypes. The survey is directed towards future design iterations exceeding this project. The test subjects of the survey are the same group that formed the respondents of survey 01.
The survey consists of four phases: 1) product presentation, 2) user test, 3) questionnaire and 4) evaluation.
The user test is constructed as an expert review with emphasis on a cognitive walkthrough of the users to test the overall usability and functionality of the tools. [Plaisant & Sneiderman, 2005, p. 142] The results are definitions of specific errors, issues and suggestions of improvements regarding the specific tools. These results are gathered through the questionnaire.

Questionnaire

The questionnaires are directed towards specific areas of investigation and serve as documentation of collected data and knowledge. The results are compared, analysed and evaluated before integrated in the product design.

The written questionnaires in use are concise and brief, with few topic specific questions. Categories are limited and alike offering little variation. Trials have been conducted as well as approval by supervisor ahead of the executions. [Frary 1996]

Two questionnaires are introduced in the project, the first supporting survey01 in the Tool concept phase and the second being the evaluation of the prototypes in the Tool design phase (survey02).

The two differ in approach as well as in gathering and storing of data. The one supporting survey01 is based on users qualitative interpretation and self-assessment, whereas the questionnaire in survey02 is focused towards more quantitative measuring methods and simple check box answers.

Material regarding the methods used in the project is found in the Appendix chapter.

Trade off between validity and reality

In order to gain primary empirical material the survey has taken the possibility of triangulating quantitative and qualitative methods. A survey was conducted in order to understand the preferences of professional staff at Friis & Moltke?). This has provided a great opportunity of applying the tool to the complex reality of the respondents.

First a survey was produced and organized accordingly

Second a test pilot survey was conducted with students of A&D in order to calibrate the procedure and gain the highest validity possible

Third, the first survey was conducted with 3 respondents at Friis & Moltke.

Fourth, the second survey was conducted with 1 architect at Friis & Moltke.

It should be noted however that the amount of respondents are not significantly valid for a broader generalization of the research tool. It does however apply a reasonable product, though one should keep the insecurities in mind.

BACK GROUND AND CONCEPTS

THE CHAPTER UNFOLDS A SELECTION OF CONCEPTS TO SPECIFY THE DIRECTION OF THE PROJECT AND THE DEVELOPMENT OF THE ANALYTICAL TOOL.

3.1 Architecture

HEALTH CARE DESIGN BEING THE MAIN TOPIC IS INVESTIGATED WITH REGARD TO THE THREE MAIN CONCEPTS OF ARCHITECTURE, SOFTWARE TOOLS AND EVIDENCE-BASED DESIGN.

As part of framing the problem statement of this thesis architectural health care projects are investigated. The architectural company Friis & Moltke, Aalborg and the Medicinerhuset hospital building is used as cases in the studies.

Friis & Moltke Architects

Profession: Architectural company

Offices: Aalborg, Aarhus & Køge

Aalborg office: Director Palle Hurwitz

Department for health care architecture

Head of department: Gudrun Østergaard

Number of employees: 10-15 in-house varying of the project size.

Department experience: 16 years, 30 health care project, small to large scale.

Medicinerhuset

Owner: Region North

Developing counsellor: Friis & Moltke

Architect: Friis & Moltke

Size: 36000 m2

Beds: 170

Wards: 7

2 Beds pr. bedroom

Price: 535 mill. DKKr

Planned: 1997-2000

Constructed: 2000-2005

Health care concepts; Patient centred health care, Patient safe health care, Future proof health care.

Admissions: 11.000 pro anno*

Length of stay: 5,4 days per patient*

Patient satisfaction: 95%*

Employee satisfaction: 90 %*

*Survey from 2007. Next accreditation is due fall 2010

Health care projects and scale

According to the medical online dictionary health care is defined as:

“The prevention, treatment, and management of illness and the preservation of mental and physical well-being through the services offered by the medical and allied health professions. –[Medical-dictionary.com, accessed the 01.04.2010]

The understanding of the health care definition relies on contextual parameters, trends and tendencies. The above mentioned subjects treatment, management, illness, well-being, service and profession differ from project to project, which is to be accounted for when planning, designing and building for health care. Danish health care tradition, social culture and geographic location result in demands and requirements different from what is in evidence in e.g. American health care. [Ulrich, R., InterviewA]

Health care architecture ranges from small-scale building projects such as nursing homes for the elderly or specialised clinics, to larger buildings such as community hospitals or clusters of service facilities.

Designing new hospitals

The hospitals have been subjects to massive improvements and redefinitions during the past century. From the pavilion structure of the late 19th century with sections scattered over a larger area, to the skyscraper block hospital of the 1960’s, with all functions and services in one building, over the trend of creating special clinics geographically separated from main buildings to the present tendency of designing very large scale clusters of health care and treatment. [Dirckinck-Holmfeld, K. & Heslet, L., 2007]

Danish hospitals have to be designed to encompass and obey basic demands such as Building regulations, BR08, Danish standards, DS, Fire regulation, Work-environment, Food Control and hygiene and other regulations of law.

Aside from these general rules a design proposal is furthermore judged on behalf of the building developers vision and expectations in areas such as output performance, service, cost and health care quality.

Health care concepts

Regarding the definition of an architectural health care project, a health care concept can often help the architect to navigate the direction of the design plan.

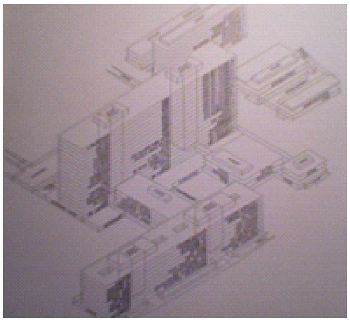
Following are a selection of examples observed in hospitals and other health care projects. Hospital buildings can consist of a variety of concepts, with more or less emphasis on each concept area. [Frandsen et. al. 2009] [http://www.nyeahus.no/modules/module_123/proxy.asp?iCategoryId=50&iInfoId=1375&iDisplayType=2]

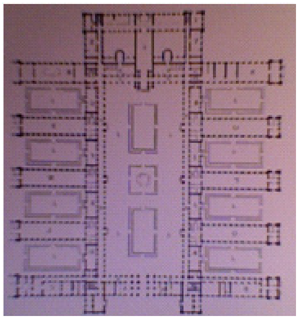
Future-proof health care

Flexible buildings, customised for change and alterations meeting various development demands

Technological improved health care

Rich embedded technological functionality and awareness of inventions that rely in technical,





digital and media contributions in health care

Patient centred health care

The patient situation during the treatment is in focus and the environment and services have been designed to fit the patient in the best possible way

Evidence based health care

Evident knowledge, experience and research are foundations of decision regarding physical form, organisation, utilities and functions

Patient safe health care

The services and built environment focus on the safety of the patient and the best possible treatment with the highest rate of recovery and satisfaction

Empowerment health care

The patient is empowered by the environment and the services to take responsibility for own healing and treatment, playing an active role.

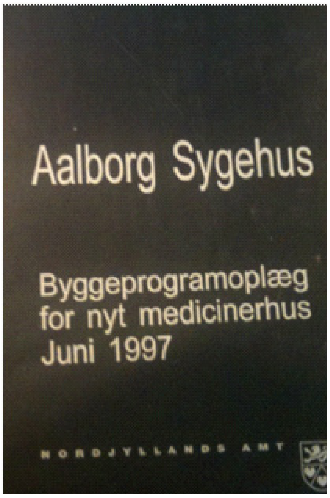
Using these concepts help communicating the focus area within the design plan.

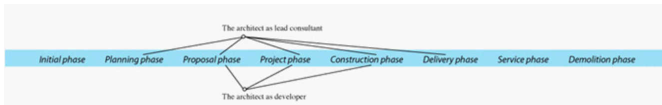
List of building demands

Designed by the architectural company, Friis & Moltke, the hospital building, Medicinerhuset, was finished in 2005. The early design manual provided by the building developer list a demand that the new construction is to be designed with emphasis on the use of evident knowledge and experience and with focus on patient centred health care and treatment. [Nordjyllands Amt, 2007]

The demands are from the initial building phase very rough defined. Friis & Moltke have invested many working hours in defining new architectural concepts based on evident information and experimentation.

Chosen by the building developer, the responsibility for assessment of the project demands and each imbedded design criteria lies with the building developer. The assessment is often done ad hoc throughout the process to steer and control the design progression. This is a





process where developer, architect and counsellor are engaged and the structure of organisation is often different because of varying stakeholder in each of the building phases. [Friis & Moltke, InterviewA]

Building process phases

Although building projects may differ in scale, content and context some basic project phases drives major parts of the building processes. The phase descriptions by the Trade Association of Working Environment, Building and Planning, BAR (Branchearbejdsmiljørådet for Bygge & Anlæg) constitutes a good and valid representation, developed by a broad collection of trade associations within the Danish building and planning industry [www.byggeproces.dk, accessed 08.02.2010].

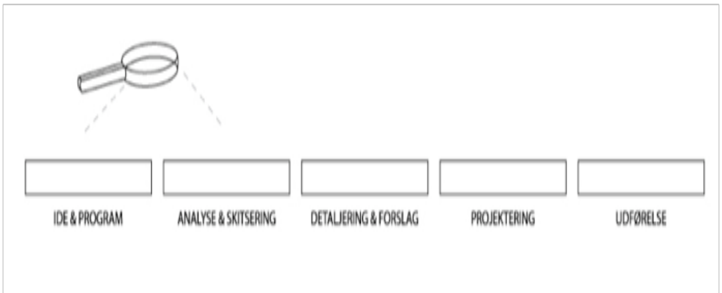
An analysis of the building organization of Medicinerhuset and Det Nye Universitetshospital, Skejby (DNU) reveal the importance of the architect, as both designer and consultant. During the pre-project phases Medicinerhuset Friis & Moltke were engaged as architectural consultants in the planning and proposal phase. During the main project phases Friis & Moltke played an active role in the project phase. During the construction phase the architects supervised along with technical advisors.

Design process phases

In each of the project phases, the architectural company operates within a routine determined workflow specific to project and company traditions.

At Friis & Moltke the pre-project phase of the overall building process is subdivided into the architectural design phases idea&program, analysis&sketch, detail&proposal and project planning.

These phases characterise a general layout of the design process coordinated within the overall building design process.



Information control methods and tools

Navigating between the overall building processes, the company's own design process and maintaining the overview of demands, progression and tasks require structure methods and organisation tools.

Methods to systemise goals and criteria are often either documents and tables, spreadsheets or online databases that can be shared among relevant stakeholders of the process. The tools and methods commonly used are displayed in the diagram below.

Friis & Moltke primarily use digital applications and tools for detailed technical drawings and visual presentation, with CAD software primarily used for two dimensional and 3-dimensional representation and communication in the later parts of design process.

To maintain overview of building projects, digital tools of systemisation are used; LEAN, ABC-planner and LUDOC. The tools are applied with increased diversity, from organisation of documents and contacts, to sharing of knowledge, drawings and data.

Methods

DDB: The Digital Construction, Digitally based exchange paradigm in building projects.

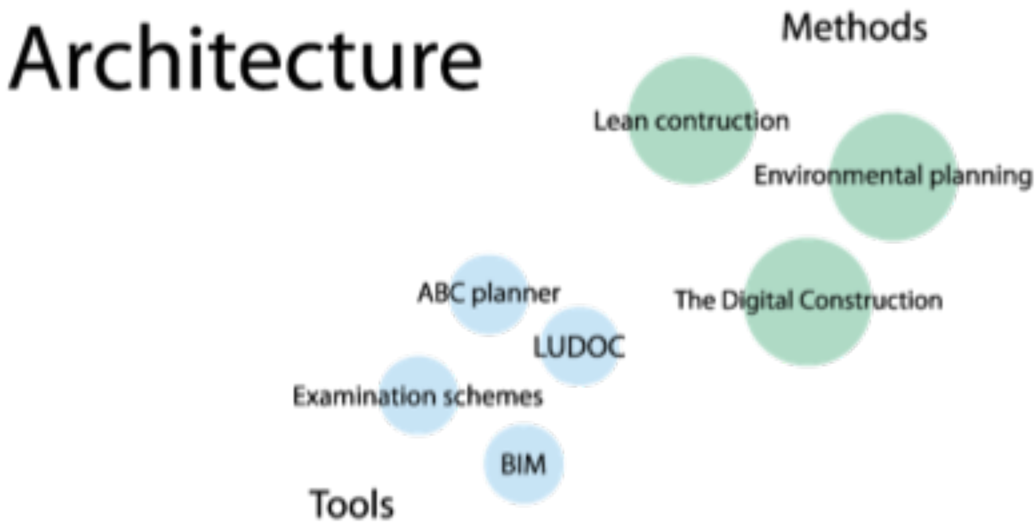
LEAN: LEAN Construction, Information and organisation planning system for building projects

EP: Environmental Planning, Environmental sustainable planning paradigm

Tools

ABC-Planner, EP systemisation tool

BIM: Building Information Modelling, 2D/3D CAD project managing, Revit.



Examination schemes; Document based self-assessment goal and demand evaluation.

LUDOC: Documentation IT-tool. Used to update and combine experience between stakeholders in the building process.

See Appendix 01 for a thorough explanation of the individual tool.

Summary

This thesis focuses on the design process of the architects, which is influenced by the overall building phases of planning, proposal and construction.

Depending on the scale of the project the architect needs a tool that can manage information and organisational objectives.

This thesis focus on the information level regarding evidence based knowledge in the design process.

To be able to fulfil the objectives and criteria within the health care concept and the focus on evidence-based design the architect need an intuitive tool that is capable of evaluating whether criteria have been met and inform the architect when information regarding the design task is needed.

3.2 Evidence based design

The evidence based design concept is discussed as to direct the use of evidence-based information in the prototypes.

Evidence-based design definition

Evidence based design in health care is a method to ensure that the construction is a result of design choices founded on valid and reliable knowledge.

Evidence based design is defined by architect and associate professor Kirk Hamilton, A&M, Texas University, by the following definition

"Evidence-based design is a process for the conscientious, explicit, and judicious use of current best evidence from research and practice in making critical decisions, together with an informed client, about the design of each individual and unique project". Strichler & Hamilton 2008

The information input definitions worth noticing are; best evidence, research, practice and informed client. They point towards different methods of 1) gathering knowledge, 2) interpreting knowledge and 3) using knowledge in the design phase.

Evidence-based knowledge discussion

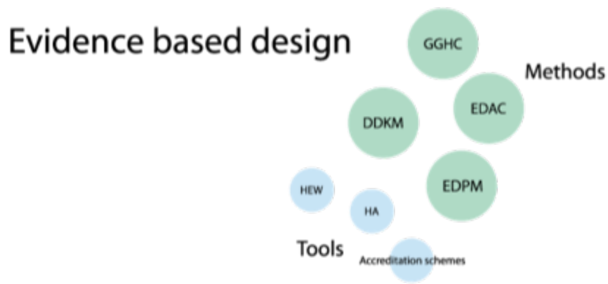
The methodological approach to evidence based design is discussed while the thesis operates within the mixed field of natural science in medicine, geometry and mathematics and social cultural science of architecture and healing.

Where natural science emphasise the use of quantitative empirical survey data based of a number of isolated experiments and observations, social and humanistic science value empirical qualitative data through multiple interviews of a subjective character, that way triangulating the two dominating methods limiting the fouls of each if applied individually.

When different fields of science meet under a common theme the methodological approaches cannot be one way oriented since they operate on different terms. The validity of knowledge is to be sought within different scientific areas and practices.

The volumes, the lighting, the construction details and functions of a building are quantifiable measurable aspects of architecture. Sensing the building, the individual perception of scale, detail and design is beyond general quantitative measurement. The subjective nature of perception depend on the individual contextual prerequisites, the state of mind and sensing-mood making the establishment of general specialised guidelines of architectural design a complex matter with many unsolved questions.

The philosophies of science that addresses the qualitative aspects of architecture and human perception are that of hermeneutics and phenomenology. Philosophers Heidegger and Gadamer address the concept of creating general guidelines and valuing architecture. Seeking a common truth



Evidence-based knowledge in the design process

The practice of EBD in architecture is divided into increasing levels of EBD gained, used and documented in a building project. Depending on the use, an EBD practitioner can evolve from level one to four, four being the upmost EBD process level [Hamilton, 2009]:

Level 1; Critical interpretation of research

Level 2; Hypothesis and Measurement

Level 3; Unbiased Reporting

Level 4; Peer Review

Being able to use EBD, depending on level, requires gathering of data and information, own research and exploration, measurements, calculations and modelling followed by documentation, sharing and writing of research reports.

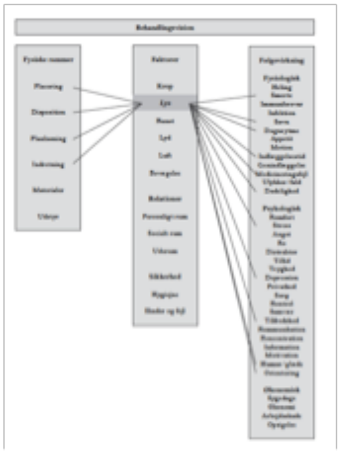
To convert EBD knowledge into practice and into design solutions, methods are to be applied and in some cases invented in order to draw the link between documented guidelines and know-how into sketches and physical form making.

Evidence-based design methods in health care architecture

Building developers of health care projects often embed evidence based design criteria in their building program.

In Denmark evidence-based design, have been used in recent hospital projects, such as Medicinerhuset, Aalborg and the ongoing building project DNU.

The investigated methods are based on diagrammatic relations between subject categories supported by explanatory documents and in some cases links to supporting and relevant research material.



Healing Architecture; a bibliography of evidence based research material

The publication HA provide a schematic method linking the relations between healing vision, physical building frame, health care factors and following physiological, psychological and economical effects. The factors covering topics as body, relation and safety are the main focus from where the web of relations is drawn. Each topic consists of an amount of related peer-review articles and publications supporting the topic. This method represents patterns of relations instead of unambiguous facts towards optimised results in healthcare architecture. It is a design concept where the main topics of the projects design foci. Only evident topics have been applied in the wheel and together with the program for the building project and the bidding demands this constitute the functional, planning and architectonic prerequisites of the design proposal.

Healing Environment Wheel, HEW at DNU

DNU uses EBD as a method to ensure evidence- and knowledge based design in the planning phase of the project, to keep up with the latest knowledge and data available and to assess whether or not this can be used within the frame of DNU and will provide value to the project, the patient and the staff.

DNU further uses EBD for environmental planning alongside documented research and combines this with use of "best-practice" from all contributors.

DNU have developed a method, HEW, that is used as both visual and written documentation of the

Having used the HEW to select the focus area within hospital design, DNU, as part of an extensive architectural design manual, uses the relational diagram method of HA to locate the relations between the physiological, psychological and economical parameters in the HEW.

ArchiMed

ArchiMed, a consultancy company certified by EDAC, has developed a method of approach, named The Evidence-based Design Process Model, EDPM, to best incorporate EBD in the design process. It divides the building process into three categories:

a) pre project, b) project and c) building/maintenance.

The EDPM consists of a number of EBD steps that the designer should address chronological simultaneously defining the vision and goals of the building project.

+ The EBD steps are:

+ Define evidence-based goals

+ Find relevant knowledge material

+ Critical assessment and interpretation of evidence

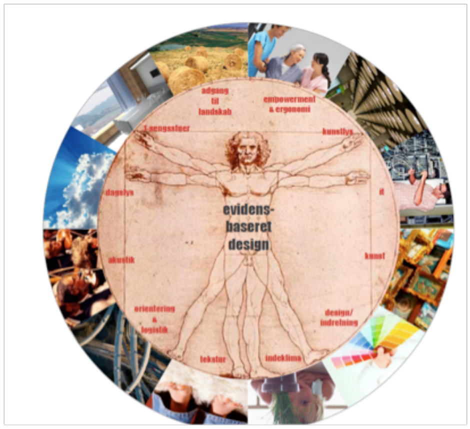
+ Make evidence based concepts

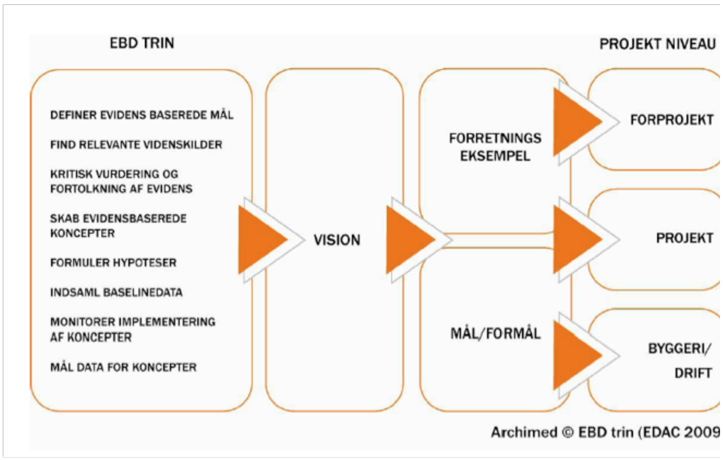
+ Derive hypothesis

+ Gather baseline data

+ Monitor implementation of concepts

+ Measure data from concepts





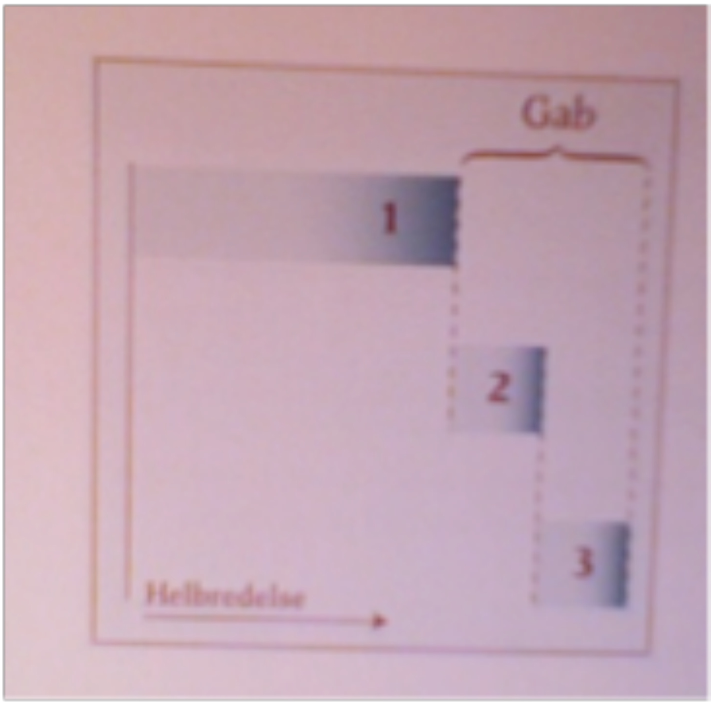
This EBD process is looping during the project so that the evidence is continuously evaluated as the project progresses and new data is gathered. Each loop should produce research material to be published, approved and used in other loops.

It is difficult to argue that one approach is better than the other, instead they constitute each other in different areas. A significant experience is that the companies borrow from each other in order to develop a design. This shows the importance of sharing knowledge and not being limited of use in promoting reliable intensions and results.

Hospital of the Senses

As input to the discussion of EBD and its significance in the future health care development the Danish publication Hospital of the Senses (Sansernes Hospital), argues that the real focus should not be on EBD itself but the humanistic interpretation of the hospital [Dirckinck-Holmfeld, K. & Heslet, L., 2007].

In Hospital of the Senses, the authors, propose a methodology of the same name as the publication, in which technology, science and clinical experience is embedded within the hospital design but in a subtle and tacit way, that humanistic values and stimulating environments colour the perception of the hospital, both from the patients, staff and researchers point of view. By focusing on the healing process of the patient they advocate that evidence-based medicine is the main contributor since it is the heritage of today's science in medicine and healing. But there is a huge gap in the mindset of healing from where the medical practice ends and the period where the patient is subject to nothing but healing and patience. To optimise the healing process this gap is filled with two main topics; that of evidence-based design and that of the effects of the paradigm of Hospital of the Senses. EBD is proven to optimise healing processes and documentation on this is being collected but the healing effect of embedding art, architectural space, sensing places toward a hospital that focus on the patient and the healing instead of the technology and the medical practise is necessary.

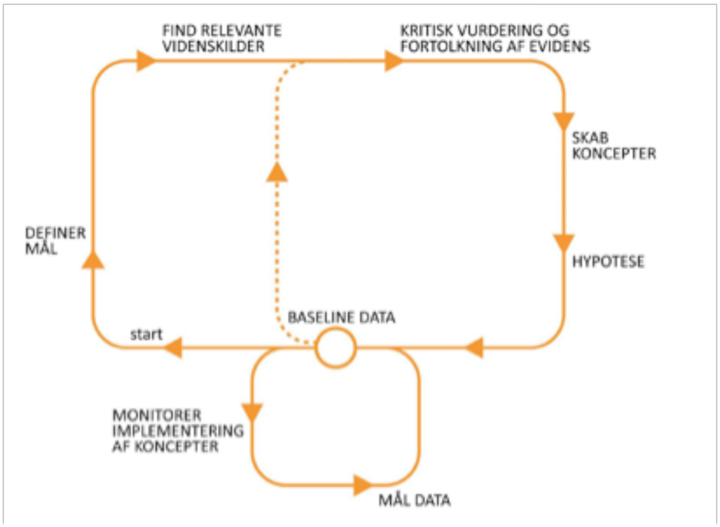


Concatenation of methods

The outlined methods in this section have an intentional use weighed primarily on the initial parts of the design process, in visualisation and systemisation of vision, demands and requirements. HA and DNUs' HEW are ways to document where emphasis lies and how it is related to each other and healing parameters. The overview on EBD topics in the design process is supplied by the EDPM of ArchiMed along with the definition of EBD practicing levels by K. Hamilton.

A crucial topic in the DNU design strategy, as well as ArchiMed's, is the gathering of baseline data and monitoring of EBD concepts during implementations of EBD concepts. The gathering of baseline data is interpreted as being evaluating experiments, specialist data and simulations and analysis of the design parts in question e.g. determination of objects location in design of patient bedrooms. The monitoring of data is a process implicated in the last part of the building process.

According to the diagrams these baseline data gatherings, assessments and evaluations prior to crucial decision-making, all take place in the latter parts of the design process, after the pre-project have been delivered and the architectural proposal won, meaning that the level of information in the initial parts of the project is up to the designer to imply. Little performance analysis, simulations or calculations are done before contracts have been made and the project phase is well underway.



Instead of working with experimentation, trial and error and evaluation in the initial part of a project time, effort and cost could be minimised if baseline and monitoring data could be introduced and implemented as a foundation of the design phase instead of being a consequence in the later part of the project

Accreditation concepts

The Danish ministry for Health is executing an accreditation and documentation program on public hospitals performance, a process that is initiated for evaluation of present Danish health care building projects. The focus is on performance and service operation.

The method is named The Danish method of Quality (Den Danske Kvalitets Model, DKKM) and is a tool of assessment to determine the state of the hospital, the staff and the services provided.

The value of this post project documentation is significant when rating hospital performances but does not reflect if changes could have been made earlier in the design and building process to heighten the quality. To be able to use the accreditation results in matters of architecture and design, the specific findings are to be reinterpreted and integrated into new design processes. In order to do so, being that DKKM is not initially meant for use in design optimisation, a different assessment approach might be needed, an approach that focus on change in design prior to construction but with performance output evaluations as main goal.

Summary

Focusing in EBD to design healthcare architecture is a focus on the relations between the constructed environments, the performance of the building, the users of the building and the perception of space and context.

With regards to the existing research catalogue presented by Roger Ulrich and in Healing Architecture the evidence lies within various articles and papers proving relations between medical science and architectural and environmental factors.

This knowledge related to design parameters creates general outlines pointing towards areas where health care can be optimized and costs reduced.

EBD knowledge has not yet been deducted on evaluation on EBD buildings.

The prototypes will consist of references to evident material regarding the design task. The selection of references is done from the publications mentioned in this section. The conversion of knowledge into data and guidelines is done by evaluating the specific design task, and the results found in the material. This is again translated into parameters and drivers of the prototypes. Evidence based knowledge is used on two levels; 1) to inform the designer and 2) to derive parameters to be programmed in software. In order to increase the productivity the tool should combine information databases with actual real-time design modelling.

3.3 Software tools

The purpose of this section is to identify present technologies and software tools used in building and design processes. Derived from this is the software approach of this thesis.

Tendency and possibility of software applications

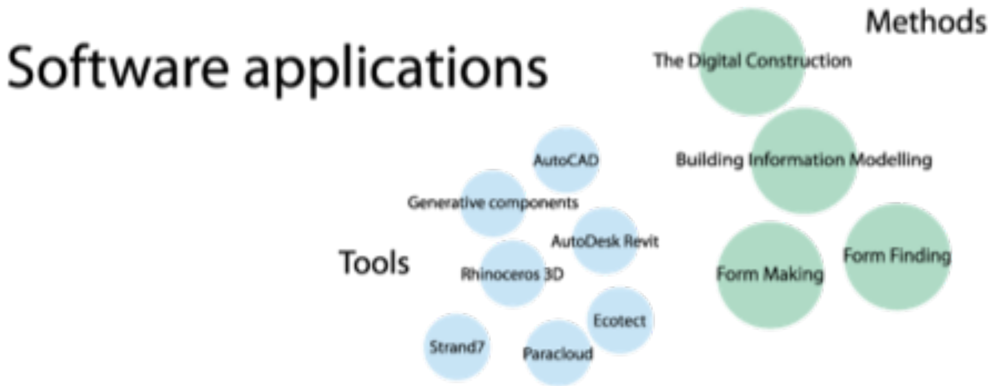
Methods and related tools each with specific functionality offer many diverse approaches for the architect. It is the combinational use of different tools for a task that enable a state of emergence in design [Kolaveric, 2003].

This thesis explores software technologies to be able to create evidence based design tool prototypes.

The use of computational power offers different discourse of digital design in architecture. Theories and concepts have been developed since the introduction of the computational powers of the algorithm. Many of the concepts share relations between computation and parameters but differ in purpose and perspective.

Design process explorations

To explore architectural form, software technologies can be divided into two overall purposes; 1) Form-making and 2) Form-finding. Form-making is driven by the designer's intentional cognitive modulation of form. The concept of form-finding is driven by a set of rules, rules guiding the design toward goals of either form or performance optimisation or rationalisation. Form-finding is a concept inspired from engineering science where calculations are the main source for optimising productivity based on informed design decisions.



Different discourses of digital architecture

Generative architecture – expressions of mathematics used to explore evolving generations of form

Performative architecture – the design progression is ruled by performance criteria of the model

Algorithmic architecture – form is derived from scripted logic and iterative optimisation loops

Parametric architecture – the design is driven by a set of chosen parameters that have specific relations and boundaries.

A specification of the discourses are found in appendix [A01.Tools and Methods]

The prototype design process of this project requires the establishment of the digital concept and a developed application platform. The concept is developed with regard to parametric architecture and the form finding concept of embedding valuable information in a parametrical modelling application.

Tools used in architecture

Different technologies are used in architecture with the integration of new tools in the design process. Technological topics as Computer Aided Design, CAD, Computer Aided Manufacturing, CAM, Computational Fluid Dynamics, CFD are not new topics.

The CAD application that have been investigated in this thesis prior to the prototype design are

AutoCAD – a software application used for 2D/3D CAD design and drafting. The software has a long history in the building industry and have a large community of users. It is compatible with the BIM standard

Autodesk Revit – is a software application programmed for the BIM standard with a new plug-in for design programming.

Ecotect – An CAD program for simulation and analysis of the performance of a model depending on the environmental parameters set in the programme.

Strand7 – a finite element analysis application used for various analysis collision controls in design models.

Rhinoceros 3D – an application primarily made for manufacturing design. It has been developed to be multi functional with full access to programming in the software development kit, SDK. The plug-in Grasshopper offers an intuitive and visually comprehensive user interface.

Paracloud – an application that processes geometric information from excel spreadsheets. It is primarily used to test designs from surface propagation.

Generative Components – a parametrical associative modelling application that handles complex datasets. Is an extension to the BIM application MicroStation

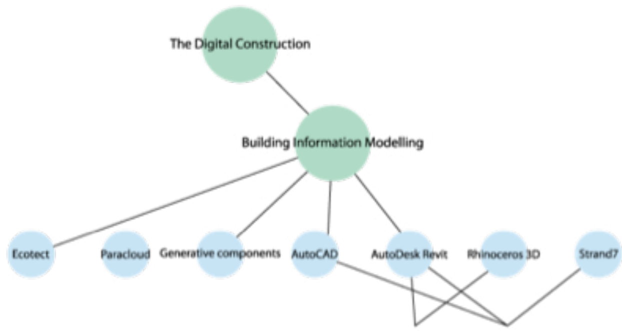
The tools have been evaluated for their potential within parametrical modelling and the functionality of embedding information as part of the parameters.

The tools AutoCAD, BSIM, Ecotect, Paracloud do not offer the required freedom regarding the parametric prototype design. Generative components although being a parametric associative program do not offer an appropriate method of embedding layers of information and metadata to the objects.

Autodesk Revit and Rhinoceros 3D with plug-in Grasshopper are the tools that hold the most promise for the prototype design.

Building process management

Software technologies are used in management of the architectural practice. Recent developments in the building industry have defined new standards to which future building must encompass. The method is called The Digital Construction and the standard Building Information Modelling.



The Digital Construction

In 2006 The Digital Construction (Det Digitale Byggeri) was implemented in the Danish building sector. Being based on 3D CAD the need for drawings and printed documentation decreased. The organisation and sharing of knowledge in the building process increased. The Digital Construction implements BIM Building Information Modelling by encompassing building design in the dynamic development of a unique 3Dmodel that is continuously updated and shared among all parties of interest through all phases of the building process.

As a tool for sharing and distributing information the BIM tool have had enormous success breaking down many barriers between professions that were before separated. The architects are now engaged in all processes from creation to production and fabrication and have become the master builders of controlled information. (Kolavaric, 2003)

BIM is a standard of The Digital Construction in Denmark and is contributing to the emergence of digital design in architectural practice.

Building Information Modelling – structure and management of geometry

The computation of various layers of information poses much potential within the concept of BIM. The property and relational parameters that can be defined in the Industry Foundation Class objects, IFC are of great potential. Layering information regarding project process and progression is a reasonable argument for a further investigation of BIM ready software applications.

The challenges of BIM are that it depends on objects and object structure, which have to be defined. After reviewing a variety of BIM object vendors few objects regarding health care are available and the property parameters of the objects are not of specific usage regarding simulation/analysis but primarily geometrical.

One of the largest evolving properties of BIM is the development of simulation application to be executed within the BIM standard.

Designers and programmers script performance relations to compound objects and units and run simulations based on relational geometric meta data.

The continuous progression in innovative use and development of BIM holds promise of emerging processes of computation on building models, environment and performance.

Rhinoceros 3D

Rhinoceros 3D (Rhino) have been the most promising software application prior to this section. It is a NURBS based design tool used by many professions within design.

The strength with Rhino is the Rhino scripting possibilities. By creating control structures in the scripting language the user can perform any geometrical operation. The plug-in Grasshopper is a very intuitive application where the user links modules and scripted components to the Rhino view and geometry. The Grasshopper plug-in provides a large amount of freedom with the scripting possibilities.

There is developed plug-ins for Rhino called VisualARQ and a Work in Progress plug-in that exports Rhino objects to IFC format to be implemented in BIM modelling software as Revit and AutoCAD Architecture. Rhino itself cannot export objects without loosing information needed to meet the criteria of the BIM method.

Autodesk Revit

Autodesk Revit offers a strong alternative to using Rhino, Grasshopper.

The new version of Autodesk Revit Architecture presents a new graphical user interface, GUI, a geometric modelling application with associative and parametric relations. The software lets the user control the digital building project at a high informational level, so that it corresponds to the BIM standards of future buildings projects.

Architectural preferences

Aside from explorative processes it is significant for the focus of the prototypes to bear in mind what the architectural companies prefer in their work with software applications.

The architectural company Friis & Moltke primarily uses 2D/3D CAD software to produce drafting, drawings and models for representation.

The software tools are AutoCAD for 2D drawing and 3D modelling, Autodesk Revit for analysis, simulation and control (still on an experimental basis) and Rhinoceros 3D for CAD modelling.

Summary

BIM and Autodesk Revit seem as the preferred choice regarding the implementation in the digitalisation of future building projects. This thesis deals with prototypes and architectural practice. The user interface of the application and the ease to which the prototypes can be developed is considered an important factor. The level of information integration and parametrical setup in Revit is considered too difficult for the purpose of this thesis where emphasis is on exemplifying functions rather that definitive product solutions. The mock up capabilities of Grasshopper strengthens this choice. In the following Grasshopper will be explained prior to the design of the prototypes.

Concatenation

To sum up this chapter the following areas have been discussed as a way to investigate the problem field introduced prior to this section

- Health care architecture
- Evidence based design
- Architectural design process
- Digital technologies in architecture

The importance of systemisation of the hospital design lies within the early design phases of the architects where visions and demand are transformed into architectural layouts and proposals.

A method of approach to support the architect in controlling demands, own visions, and input alongside providing evident baseline data in the early design process is to develop a system that can hold relevant information and give reliable associative feedback when valid information is needed prior to decision-making.

Such a system should be a dynamic user-interactive tool based on parametric associative design variables. A tool capable of; linking knowledge, storing information and data, increase communication and ensure validation, evaluation and control of performance in an optimising process of design and task specific quality of health care buildings.

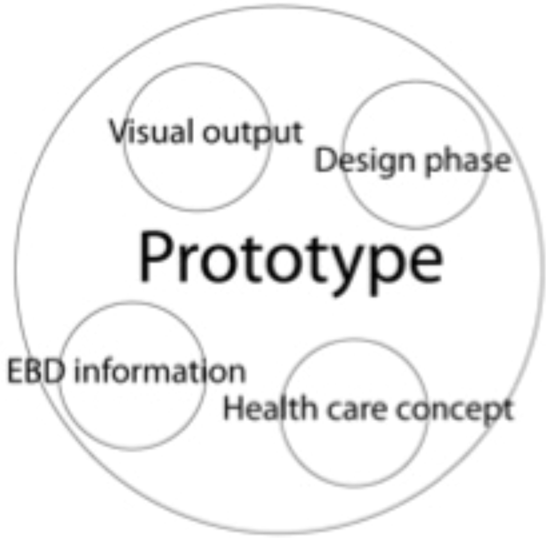
Derived from this statement the experiments done in this thesis are prototypes of a potential evidence based design product application.

The prototypes are based on parametrical modelling and test whether analysis and relational modelling might assist architects fulfilling their design tasks.

Parametric setup based on health care projects

The prototypes are developed with the following purposes; 1) matching the concept of health care 2) integrating the tools in the right phase of the design process, 3) providing access to evident knowledge and 4) creating an output that is usable for the architect, furthering the decision making process.

A focus within healthcare is chosen in the development of the prototypes. The focus is that of patient safety.


Visual output
Design phase
Prototype
EBD information
Health care concept

3.4 Patient Safety

The following section is a concretisation of this thesis focus within the fields of health care.

Focus on the Healing process

A hypothesis of this thesis is that a thorough designed environment ensures optimisation of the treatment of the patient. A more efficient method of treatment ensures an optimal healing and recovery process for the patient. The result will be a shortening of in-house patient recovery, decrease of hospitals costs and a higher survival and success rate among patients. Statistical data gathered from the Medicinerhuset supports this [Tool Scenarios, pXX]

Phase of the healing process

When admitted to the hospital the patient will undergo a general process of treatment phases.

+ Visitation – the patient enters the hospital and a diagnose is made

+ Ambulant medical treatment – the patient is treated and sent home again.

+ Admission – The patient is assigned to a specific part of the hospital depending on diagnose.

+ Medical or surgical treatment – the patient is taken into the speciality wards and here treated or operated.

+ Recovery period – The patient is lying in bed and under recovery. The patient is healing.

+ Rehabilitation – The patient is trained to reach full physical and psychological state.

+ Departure –The patient is cured or stable enough to be sent home

+ Check-up – The patient is checked to see whether or not the treatment have been sufficient. If not the patient undergoes treatment again.

The recovery period in the healing process is chosen as the perspective with further focus on the physical environment around the patient.

Evidence material on patient safety

A short review of the available evidence based date supporting the subject is done to evaluate the choice of focus.

Healing architecture

In Healing Architecture one of the three main factors of investigation is safety alongside relations and body. Here safety is further subcategorised in Hygiene and Damage & Casualties. These subcategories have been formulated on the basis of the evaluated article material on evidence- and knowledge-based data.

Dansk Selskab for patient sikkerhed

Dansk Selskab for Patient Sikkerhed (DSPS) have conducted a categorised list of patient safety factors, the possible means to contradict the unsafe aspects of health care design. An assessment value depending on the amount of evident material supporting the subject indicated how well established the knowledge foundation is.

The National learning lab project

An American interdisciplinary team of professionals and scientists have gathered evidence based design information with a focus on Patient Safety as part of a larger hospital design project. Part of the design process documentation is a design guide put together by John Reiling on how design decisions and concepts should respond to patient safety parameters in order to create a better and safer health care environment for patients and staff.

Parametric safety parameters

The material review indicates a wide number of guidelines and design rules. The design of the floor plan of health care projects is chosen as parametric offset. The material support the concept of developing evidence based parametric prototypes with focus on patient safety. This is done be evaluating the floor plan solutions and define parametrical rules regarding distance, organisation and logistics.

Exemplifications of parameters regarding patient safety and the floor plan

+ Logistics
+ Single bed or multiple bedrooms
+ Height of rooms
+ Distance to bathroom
+ Location of bed
+ Amount of space
+ Distance to nurse station
+ Windows, doors, interior
+ Relation between room and wards

Summary on patient safety

This thesis chooses to focus on the element of patient safety in hospitals.

The thesis investigates patient safety from a parametric and evidence based design perspective and is limited from implementing hermeneutics and phenomenology in the analysis.

Patient safety is referred to as relations between the physical factors of plan solutions, interior design, materials and equipment in creating an environment with focus on the patient's situation.

Seen from a parametrical point of view safety poses a straightforward process because of the possibilities of working with floor plans, object location and distance measurement.

The elements and objects can be identified and assessed from running evaluations on the floor plan delivered by the architect early in the process. The assessment of the floor plan will identify of facility conditions of the architectural plan and design, where patient safety and the quality of patient treatment is compromised.

The evidence indicates that well-designed physical settings play an important role in making hospitals safer and more healing for patients and better places for staff to work. [Ulrich et al. 2008]

Designing prototypes that optimise patient safety levels are done to:

+ improve the healing process

+ reduce medical and clinical costs

+ work with planning of the physical space of the hospital

+ translate evident knowledge into a parameter driven computation of geometry

The thesis will focus on the last two options; work with planning of the physical space, translate evident knowledge into a parameter driven computation of geometry

Evidence material issues

Instruments and means to determine the many conclusions from evidence are vague and to some extent not present.

The research experiments that the evidence guidelines are founded upon have differentiated prerequisites regarding, period, method, patient, illness, staff and treatment. Conclusions differ, and contradict other similar results. It is therefore up to the interpreter of the information to decide the relations between evidence, design rule and actual project context.

The rules are often indications that can be placed as part of a checklist of options:

"Wrong-site surgery. Standardize operating room (OR) suites; install proper lighting; install cable for access to digital images and photographs of surgery site along with x rays." [Reiling, J., 2006]

Next step

Working with computational geometry and parametric models poses a challenge since there are undefined areas between the quantitative measurement of physical space, research conclusions of evidence based material and the documented effect of the future built environment.

The question that this thesis seeks to answer is if it is possible to translate the guidelines into a useful application that can be used by the architects in the design process.

3.5 Grasshopper

Grasshopper is a plug-in for Rhinoceros 3D.

It is an associative parametric component based geometric modelling software. Being associative in it nature means that the user through parameters can change the design without loosing information or having to remodel from the beginning.

Grasshopper has an intuitive interface, a wide selection of components that gives the user freedom to use all the functions of Rhino. By giving full access to the Rhino Software Development Kit, SDK those functions that have not been designed in Grasshopper can be accessed through scripting using the VB.Net programming language.

Although being relatively slow when processing large data sets, Grasshopper is a strong and versatile tool. Considering the intuitive interface and the large community online, Grasshopper is the preferred choice of an application to design prototypes with. Being relatively easy to apprehend Grasshopper is ideal for tests with novice users.

Definitions

A file in grasshopper is called a definition. The definition contains the data that needs processing.

The interface of Grasshopper consist mainly of a background canvas, a menu bar and a selection of function panels.

The canvas is where the function components are placed, defining the desired geometry and relations.

Components

A component is a mathematical function that performs an operation, whether that being to draw a set of point, connect point to a line or calculate the angle between vectors. All components contain input and output features. These features let the user connect and assign parameters to the components, thus controlling the geometry.

Script components

If a function is not designed as a component, Grasshopper have the VB.Net scripting component, that gives the user absolute freedom to explore all mathematical and geometrical attributes of the Rhino SDK. Through this option, the user can define the number of inputs, the data type, the operations and calculation that need to be performed alongside the possibility to write recursive scripts, using subs, functions, conditional statements and loops. The script programming language and syntax is Visual Basic. Net. This thesis will not go further into detail in the technical foundations of the scripts but use them as a method to perform given actions in the prototypes when needed.

Interface

Rhino viewport

The latest development of the Grasshopper edition (which is being updated on a monthly basis due to new functions) has introduced the concept of colouring meshes in the Rhino viewport.

Colour gradients are used to strengthen the visual feed back on certain operations where needed, e.g. when a condition in the script or definition is not met, the object faces will be coloured.

Grasshopper canvas

The panel component can be used to display data strings of text from files or from within a scripted component. This is used to tell the user what the conditions are, what data is being output and what statements are being processed.

The slider component lets the user change the input value of a given parameter of another component by dragging the slider from side to side.

A relatively new feature is the Animation feature of the slider which can render a bitmap of the desired viewport at that exact slider value. This is useful to obtain and store specific information regarding a sketch or a geometric model.

In the Rhino viewport all sliders and toggle buttons can be assembled in a main control panel, making the parameter change in the Rhino viewport less dependent on the open Grasshopper panel.

In a later section of the thesis the concept of designing the user interface for the prototypes is discussed with reference to the 8 golden rules of interface design.

TOOL SCENARIOS

4.1 IT in creative processes

Integrating Information Technology (IT) in the architects creative design process is in this thesis considered an important step towards more efficient design products. As seen in other professions IT tools derived from manufacturing and production pose optimisation possibilities. The optimisation of form and performance is part of the design process in e.g. automotive design and aeronautic design.

Tool definition

A digital tool is defined as a software application that output data by performing computational operations. Computational operations are either calculations or change in distinct parameters that drive an algorithm. The algorithm is the procedural script, a coded text file of instructions and task listed in the software.

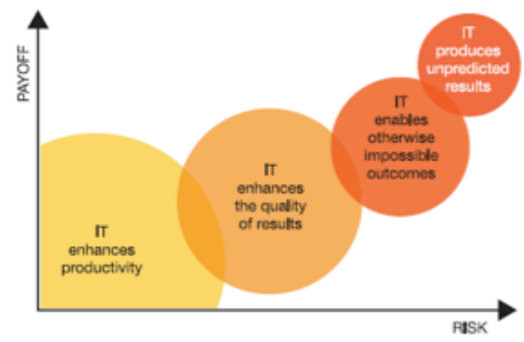
The output is in form of either visual graphical, textual or integer-based feedback. The feedback is for the user to interpret and use in the creative design process.

Tool making

Tool making is gaining more and more recognition in everyday architectural practice. Innovative use of Information technology, IT in the creative design phases can enhance productivity and creativity [Mitchell et. al., 2003].

The different levels of research in use of IT pose different levels of benefit and risk.

Architectural practices that invest in IT enhancement, use toolmaking in later project phases, at the end of the construction chain. Building information modelling, analysis and simulation tools help to control building designs and ensure higher levels of performance.



2. The NRC's four levels of risk against return.

According to Alvise Simondetty of the Arup group, London architectural designers need investment in the early design stages to raise the level of benefit.

"We should enhance the front end of the design process that's going on in all design offices. I think many design offices miss out on a major possibility of increased productivity or an improved design - the decisions made in the initial design stage affect 80% of what happens thereafter."[Simondetti, A., 2008]

This refers to the shift in using IT to focus more on design making (early in design chain) instead of design efficiency (end of design chain)

Arguing for IT in the architects design process

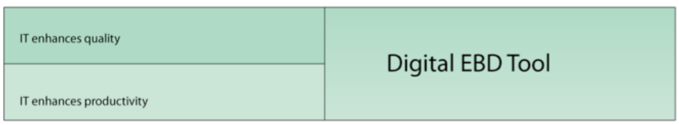
This project focuses on the development of software tools to enhance quality and productivity, both as a consequence for the architectural practice and for the performance of health care building once built.

The building design will be improved if the design solutions were iteratively analysed and evaluated on the evidence based design parameters. Productivity enhancement would increase since the architect would be saved from tedious search for arguments and calculations upon design ideas in the process.

Digital EBD Tool

The design of a tool relies on studies of human- and technological aspects of present use and the registered impact from similar tools in a related context. [Galletta & Zang, 2006, p4]

Developing the framework for a digital tool requires involvement of architects and user representatives from a selection of areas of health care.



Studies are performed on two levels; 1) analysing EBD concepts in design practice and the effect on health care 2) identifying the requirements for a software tool in the design process.

The studies consist of a series of qualitative interviews with the architects at Friis&Molke and personnel at Medicinerhuset, Aalborg Sygehus and Region Northern Jutland all parties that have or have had an active role in the planning of the Medicinerhus. This is considered a valid foundation for gathering of empirical data in development of the EBD tool.

A "day in the life" scenario [Carol & Brown] is conducted with two of the employees at Friis&Molke to identify the present work methods of analogue and digital sketching and modelling.

Future tool scenario models are contemplated with topics of user, context, task and technology and evaluated with architects and architectural students. Matching each scenario a prototype mock-up based on Grasshopper definitions is outlined.

An "envisioning" scenario [Carol&Brown] is written based on experiences throughout the studies of this thesis to point out future work related aspects of what might be proposed as a near future situation for architects dealing with BIM and health care.

The extensive description of the scenario models and analysis is found in the Appendix A02. Scenarios

Future tendencies in architectural practice

Envisioning the future practice of the architectural design field is a less tangible matter. Innovative science, working methods, financial crises, political and cultural changes are some of the societal strings that can alter the work day of architect in the future. The following is made partly by observations; literature research and points derived from interviews in the context of EBD and architectural practice and is to be considered possible plausible future scenarios.

Building industry

The governmental downsizing of budget for healthcare together with the focus on control and organisation in the building industry points towards a future where the architect will have to focus more on building process organisation and counselling regarding larger public building projects. High demand of control of working methods, costs and increasing expectations of value and output in e.g. health care building performance, reduces the amount of resources for aesthetical and creative experimentation. [ArchiMed, 2009]

Digital technologies & innovation

The growing implementation of computer technologies in building and design processes as well as the architects daily routine at work means that more time and resources are spent on software application use instead of analogue sketch and design methods. Optimising various performance criteria is done by analysis and simulations done by computer. AI technologies and evaluation application will be implemented in decision making reducing time spend on subjectively weighing all the design alternatives which used to be one of the main tasks of the architect. Methods for computing valued relations and consequences between physical artefacts and psychological sensing based on EBD data will be developed. [SSOE.com, http://www.ssoe.com/news/article2.aspx]

More tasks will be outsourced to specialists and the architect will receive a role more as creative project leader and coordinator. There will be an increase in digital network sharing and cooperative work methods, emphasising a concept of non-stationary work stations and online access to working material. [Simondetti, A., 2008]

Architectural designers will look into innovative use of tools from other professions instead of relying on traditional technologies in their work. [Simondetti, A., 2008]

The development of the Danish Digital Construction concept will be fully operational, supporting the vision of all building information located on servers, accessible for all stakeholders at any time of the process. This calls for the architect to be able to use the embedded and required technologies. [http://ing.dk/artikel/104091-staten-genstarter-det-digitale-byggeri, 02.03.2010]

Derived from these declarations is the idea of a more streamlined technological enhanced workflow, where the tools are fully integrated in the architects working tasks, organisational structure and the communication with other stakeholders in the project.

Use – studies of evidence based design concepts used in Medicinerhuset

Contributing interviews:

+ Gudrun Østergaard, Friis & Moltke, Architect MAA

+ Jytta Højslet, Head nurse, Department of Endocrinology, Aalborg Hospital

+ Heine Overby, manager of production and building, Region of Northern Jutland,

Design process

Following topics were chosen as focus areas in the design of Medicinerhuset (1996-2000)

+ Light
+ Sound
+ Air (smell)
+ Resting
+ Logistics
+ Hygiene
+ Safety
+ Flexibility

EBD

The evidence-based design concepts have been defined from the following sources:

Knowledge and experience

Education, experience and knowledge within hospital and health care design of the individual team members.

Best-Practice

The routines, traditions and project portfolio of the company have been followed.

User participation

Meetings and workshops have been held within different teams of user representatives.

Experimentation

One-to-One mock-ups have been used to test the performance of facilities and work routines.

Summary

According to Gudrun Østergaard, Chief of Health Care department at Friis & Moltke, Aalborg, EBD was a know concept. The use of EBD was not systematically organised, but used ad hoc in the different building phases. [CD, InterveiwA]

Software tools

Management

Microsoft Word, Excel and Outlook were used to keep track of the process

ABC-planner was used with excess to keep track of demand regarding environmental planning and construction.

Drawing

AutoCad was used for 2D CAD drawing and drafting throughout the process. Exchange of data between stakeholders in the later process was carried out.

Modelling

AutoCAD 3D CAD modelling was used for representations and visualisation of the project proposal.

Summary

Software analysis and calculations of climatic and lighting conditions were organised by the engineering consultants. Individual systems for keeping track with changes and demands have been evolved throughout the project in document form.

Impact – the effect of the evidence based design concepts in Medicinerhuset

Contributing interviews:

+ Gudrun Østergaard, Friis & Moltke, Architect MAA

+ Jonna Borg, Head nurse, Department of Dialysis, Aalborg Hospital

+ Anonymous, Chief doctor, Aalborg sygehus

+ Jytta Højslet, Head nurse, Department of Endocrinology, Aalborg Hospital

+ Laila Bodsgaard, Security manager, Aalborg Hospital

+ Louise Weikop, Quality coordinator, Aalborg Hospital

+ Hans Henrik Lervang, Chief doctor, Department of Endocrinology

In general the respondents are very pleased with Medicinerhuset, both on a functional level and in a aesthetic sense. Following issues have been registered regarding the building:

Health care quality

There are issues regarding the integration of natural and artificial lighting. During night the lighting is to dim and diffuse.

After sunset the large glass walls and windows turns into reflecting mirrors, which is noted as having a depressing effect on long term inhouse patients.

Patient well-being

Opposed to the vision of the patient-centred hospital patients still have to be moved around during their period of treatment (which is considered negative).

Decorations in the patient treatment areas and in bedrooms are not allowed due to the rule set concerning building aesthetics.

Summary:

Accreditation results on Medicinerhuset show a patient satisfaction at 95 %, staff satisfactions above 90 %, infection rates have decreased by 18 % and absolute staff absence decreased by 2,3 %. The average in-patient length of stay has been reduced by 8%.

Building function issues

Logistics

It is difficult for first time patients, families, and external staff to navigate due to complexity of floor plan and low efficiency signage.

Voids and empty unused areas are located in every ward of Medicinerhuset.

The café areas between wards have been closed or reinvented for other use due to the long distance for patients to walk.

The staff has long distances to walk because of the location of the functional facilities which reduces the efficiency of patient treatment.

Work routines

Chief doctors offices are located far away from the wards increasing the separation between team members of the staff.

There is a lack of staff office space.

Staff rooms have unfortunate size and location regarding work routines.

Patient waiting areas are either out of sight from the ambulatories or too close invading the privacy of other patients in the ambulatory.

Design process

Political interests have requested for a replacement building instead of new, resulting in limitations of following future increase in production.

Statistical analysis of working hours and staff procedures has been the basis of calculation of space and offices resulting in too few facility square meters.

User participation by staff groups has been more of political than practical topic, resulting in negotiation difficulties regarding functions and facilities among the staff groups.

Software tools

Design phases

There has been a request for a more systematic procedure designing the hospital.

At the meetings with the user representatives a lot of information were exchanged. It was at times difficult for the architect to collect and organise all information.

Summary of use and impact

“It is a paradoxical, but we must probably face the fact that despite all our efforts the perfect hospital is unbuildable. It is impossible to accommodate every demand and request to the finished building” – Chief doctor, Aalborg Sygehus

No doubt that the house of medicine is a large facility, working with multiple and intangible professions. With 168 patient beds, 828 staff members, more than 11.000 inpatient stays, 90.000 ambulatory visits and a budget pro. Anno of 560 million Danish crones, the 36000 m2 of hospital space is an example of a building with no architectural compromises and only few known issues. Few patients make notice of the problems issued and are in general very satisfied with the received treatment.

Derived from the studies are areas of significance to the development of this project. The notable architectural issues regarding the staffs working routines indicates that the user participation have been either to poor, the suggestions deprioritised or the understanding of the consequences lacking.

Though patient-centred health care has been one of the main priorities of the building developer and the architects there are issues regarding aspects of the patient well being.

As one of the respondents argue; "The hospital has been designed by healthy people for healthy people" and continues "...healthy people do not seem to really understand how dramatically your life needs changes once you get sick!" The significance of the mindset and the immediate situation of the patient is crucial to the design patient-centred facilities. [CD, Medicinerhuset, InterviewC]

Evidence is building up around the fact that the healing process depends on the patient's sense of the well being and state of mind. The length of recovery increases if the patient feels uncomfortable in the environment. [O'Niell, 1991a]

Although hospitals are business facilities it is possible to integrate an environment that can be converted into a more familiar setting, depending on the state and mindset of the patient. The example of rules against Christmas décor or the consequence of setting of the fire alarm because a nurse lighted a candle on new years eve, though a banality, is an important aspect to bear in mind when trying to create a setting with fast and efficient process of healing as main goal.

During the design phase the architects did not have the time or the funds to explore evident material of the design criteria and there were no overall EBD design strategy at the time.

The conclusions to be used in the design of the tool are

+ Clear strategy for the use of EBD early in the design phase

+ Systematisation for organisation, communication

+ Clear strategy for user participation, users needs and requests

+ Evaluations of design solutions and development of guides to relations and complication control in health care design.

+ Links between relational areas with visual feedback of issues and consequences in the design plan.

+ Integration of CAD software tools in evaluative design situations.

Present approaches

The present method and use of evidence is not different from the process of Medicinerhuset and the new design of Thisted hospital, a project recently won by Friis&Moltke.

The "day in the life"-scenario was conducted within the frame of the work process of the recently won competition, regarding a hospital project in Thisted, by Friis & Moltke. It indicates that there is little difference in the EBD method used in Medicinerhuset (1997-2000) and at the project in Thisted (2010). A progression is observed in the implementation of CAD software in the early design process, with a growing influence of BIM and Revit in the CAD management.

Sketching is mainly done analogue by hand and paper which is valued very high. One of the two architects would like to have more time for experimentation with the software applications as part of their work.

EBD Tool scenarios

The tool design process operates in four categories, each defining specific characteristics of the tool. The categories have been redefined based on the investigations made fitting this thesis.

Tool - User – the potential users of the tool, whom is expected to use, operate, interpret and evaluated the functionality

Architects, Engineers, counsellors, building developer, specialists, user representatives

Tool - Context – the context in which the tool is to be utilised, perform, and have impact

Architectural design, design processes, health care, building industry

Tool - Task – Definition of functionality, utilities, operations and tasks to perform.

Increase and optimise the quality and performance of the built environment. Evaluate and document the impact of the building prior to construction.

Data processing, documentation, referencing, evaluation of digital sketches, drawings, models, Provide visual feedback

Tool – Technology – The kind of technology that the tool rely upon and consist of

2D/3D/4D CAD software, BIM, Database processing, LEAN construction and The Digital Construction.

BRUGER	Primære; Arkitekter og designere Sekundære; Ingeniører, fagspecialister
TEKNOLOGI	CAD, BIM, Det Digitale Byggeri, LEAN
KONTEKST	Arkitekt virksomhed Sundhedsarkitektur og design Designproces Byggebranchen
OPGAVE	Øge kvaliteten af det færdige byggeri Dokumentere og påvise effekten af byggeriet forud for opførelsen

The implementation of the tools in the design process is found important in this thesis. The decision of where in the different phases of design to implement the tool requires the identification of a) where support is needed the most b) what kind of support is needed and c) how support should be implementet in the architectural design practice.

4.2 Tool scenarios

Three scenario models have been made each with specific possibilities and requirements regarding design process, technological aspects and methodological strengths.

Prototypes have been designed as "quick and dirty" application mock-ups following the approach of Rapid Application Design. The prototypes support the scenario models A, B and C as an exemplification of the functionality and utility of each scenario model. The full description of each prototype is found in [Appendix.03. Prototypes]

The prototypes are used as investigations in the overall design topics of the EBD tool. The tests have contributed to the definition of the basic functions of the prototypes.

The scenario cards display the differences in each development concept for the application tool. The subjects are a) Phases of design, b) Technology, c) Methods and Functions.

Scenario A

The tool is itself a basic modelling application. The designer enters project specific data into the application and receives diverse output from which his/her design is guided.

The tool requires no previous developed CAD models, little experience in CAD modelling, limited knowledge in health care projects but a basic idea of the concept of the project.

It is the purpose that the designer can begin to layout ideas and concepts of form and function in a geometrical ruled and evaluated way while receiving immediate feedback and references to results and extensive knowledge.

In addition to the conceptual design of the floor plan other issues and evaluation parameters will be introduced to the designer to create a more informed design plan.

The tool is used in the idea/program phase and the sketching phase of a project.

Scenario B

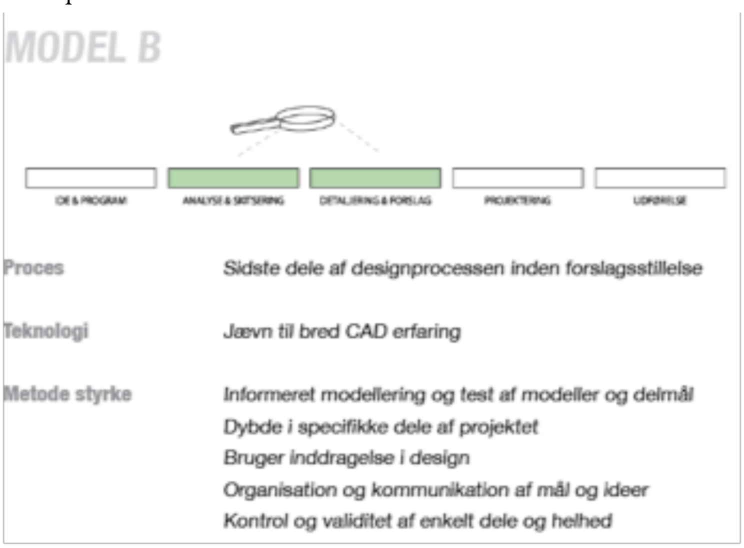
The tool is designed to match a specific topic in health care. It is primarily an evaluation tool to support or test specific elements that the designer is not capable of judging by himself.

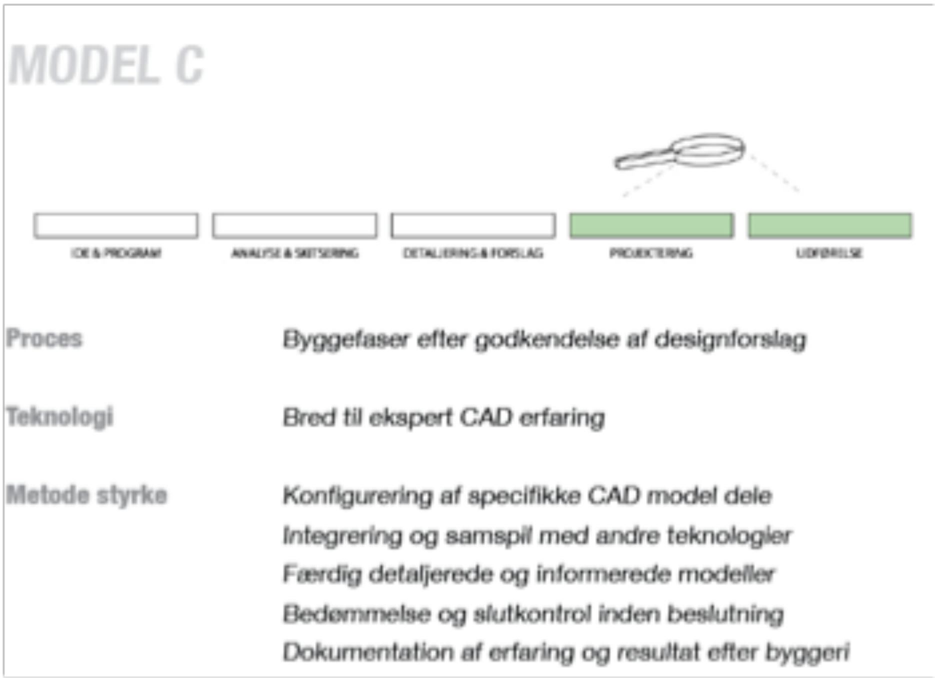
The tool is fed with a part of a CAD model already made within a CAD program. The model represents the designers ideas of a parted solution merging his/her architectural vision with functional goals and requirements.

The designer chooses from a specific list in which areas the plan is to be evaluated

The purpose of the application is to test and rate specific parts of the design layout prior to further development. The tools feedback is part of the critical decision process.

The tool is used in the sketching and in the early part of the detailing phase of a project.





Scenario C

The tool is an extensive application that evaluates and assesses larger plans and models.

The tool requires a detailed 3D CAD model that has been developed as a part of the Digital Construction paradigm.

The purpose of the tool is to create a valued list of specifications that give a overall score showing how well the project is expected to perform when built, based on evidence based research and results.

The result is intended as a tool to help the developer guarantee optimal performance of a building project.

The application is primarily intended the detailing and proposal phase of the design phase as well as the project phase regarding the overall building process.

4.3 Survey 01 - Scenarios

As evaluation of the scenario models an empirical survey have been conducted with Friis & Moltke and a group of architectural students. The feedback has provided the thesis with important data regarding the development of the tools.

Survey on scenario models

Following are the three main goals of the survey:

+ To acquire valid statements on scenario choice from professionals

+ Identification of inconclusive areas, further explanation needs and specific development cases.

+ Indication of potential usability of tool functions.

Method

The survey is tested on a selected group of students of the Architectural education at Architecture and Design. Both supervisors prior to the execution of the survey have approved the questionnaire.

As explained in [Methodology, p. XX] the survey consist of four phases; 1) Presentation, 2) Discussion session, 3) Questionnaire and 4) Evaluation.

The presentation slides, the questionnaire and the resulting diagrams and a description of the survey are found in [Appendix, Survey01, p.XX]

The methodological aspects regarding the processing of the survey is furthermore found in the appendix.

Result

Because of limited amount of respondents the test group respondents have been compared to form the results of the survey.

The most significant outcome of the survey was that in order for the tool be more effective for the architect it should be directed towards the building developer, whom are to enforce the use of the tool upon the architects and the judgement panel when architectural proposals are evaluated. This will create a common ground for competing firms and judges with differing preferences.

Another factor is the integration level on computer technologies in design processes. In conclusion it is not the increase of computer application use that poses a threat to creativity, it is the way the applications appear, are used and integrated in the work routines that is important. Emphasis in the application development must be on human-computer interaction more than to which parts of the design process the tool should be included or excluded.

Third is the importance of informative design decisions using research information, experience, best-practice and user participation.

From the survey the following changes and contributions are made to the tool diagram to finish the concept development:

The user group encompass the building developer ahead of the engineer and specialist group.

+ The basic functionalities are preferred to be able to steer, control and maintain goals and tasks of the project as well as easy communication across professions.

+ Linkage between utilities and evidence-based information is weighed as functionality.

+ Enhanced possibility to use the tool across a wider range of the projects phases, from sketch to detail.

+ Enhanced user participation through visual sketch and immediate assessment response by using CAD sketches.

+ Because of rigidness in analysis software and limitation of creativity the ability to toggle the evaluation functions and feedback on an off is an option.

+ The functions should declare to which level of consistency he/she must obey the feedback, being either guidelines or rules.

When it comes to the validity of the survey the number of respondents are to little in order to assess whether or not the results are valid enough to represent the general user group profile. As to this project the results still give direction towards possible areas of issue, interest and development, and is therefore used to further the project.

The following parts of the thesis will experiment with prototypes testing selected functions described in the concept model.

Prototype Scenario model

The following is a conceptual layout of the digital EBD tool that this project in the following will design prototypes for:

The scenario analysis methods on both strategic planning and human-computer interaction have revealed information of actors, background and assumptions of work environment, goals and objectives and the sequences of actions and events.

The following is a further concretisation and the last scenario iteration prior to the prototype design. The scenario is the foundation of the prototype application design:

+ The user group is limited to only focus on the architects role as designer in the project process.

+ Technological the focus is on CAD drawing and modelling in 2D and to some extent also 3D

+ The functionalities are that of visualisation of undesirable architectural propositions and design decisions.

+ The references to evidence based information regarding design tasks are embedded in the prototype design.

As a method of envisioning the future potential use of the tool a narrative scenario from an architectural practice is described. It shows the hypothetical "day in the life"-scenario, a work-day of an architect working with health care and the evidence based design tool. [Caroll, J.M. & Go, K., 2004, p.47]

With this future scenario the concept development of this thesis ends.

4.4 Log book

Jonas Berg, architect MAA, 35 years of age, graduated from the academy in 2005 in Design of larger health care projects and utilities

Is an employee at an architectural company of reasonable size. Works within the department of Health care.

Log: 20.03.2015

"10.00 AM: Met in at work late today. Worked past midnight last night. Had to finish the floor plan and send it to the project manager. Will start with the sketching on the bedroom layout for the design proposal of the new hospital before meeting with the client later."

Jonas is logged in on one of the shared workstations at the company office. His last login is from last night from his home laptop computer. A registry file is sent per email to the account manager as documentation of the used work hours. His personal desktop is loaded with access to his personal user profile, the shared file database of the projects that he is attached to and the relevant file updates made by colleagues and other stakeholders since his last login. A popup message from the Research database reminds him that there is a updated article holding evidence on Wall colour and the effect on depressive patients. Since this refers to a already finished project Jonas tick of the reminder for now

He starts up the Digital construction application. He decided to see how far the construction of the psychiatric ward is. The 3D model is loaded while the realtime updated model shows the progress of the building. A chat message pops up from his friend who is working on the construction site. They are installing the windows on the second floor. He clicks into the construction and manufacturing section to discover that images from the site have been attached in the model as well as window detail.

He starts a new session in the application and names it Bedroom_Sketch_Patient Safety_Aalborg New hospital.ebd. After setting up the CAD interface the program promts him about project specific detail, such as type, function and EBD focus areas. Jonas tick on references to the Research database regarding Patient Safety, Bedrooms, Medical Ward. After this he chooses a novice skill level, since he finds himself rather inexperienced in matters of patient safety.

From meeting with client Jonas' boss have already drawn an outline sketch of the building plan which Jonas loads into the application.

The sketching progress fast as Jonas gets immediate feedback upon the spatial organisation of the bedroom. Jonas exports his sketch and the comments made by the application, and checks of "forward to stakeholders". The file is stored on the server and an email is sent to his colleagues working in the same project, that they must comment on the sketch.

"01.00 PM: Had a meeting with the client down town. Presented my sketch at their digital whiteboard. Issues with the logistics required contact to the user representative. Additional changes were made on site."

Jonas is back at the office from the meeting with the client. At the meeting he logged on to their network and again gained full access to the his project server. Using the digital whiteboard the sketch of the bedroom was presented. The client had trouble reading the 3D CAD model, so 2D representation was chosen. The diagrams and plans of the applications helped with the understanding. The client had some additional changes, there had been a budget cut so less m2 were available in the design for the utility room next to the bedroom. Jonas changed the parameter of room area. The associative model was updated, the new approximation of cost was calculated and hence approved by the client. The user representative of the logistics group was contacted by phone and invited to a videoconference using his own laptop. After reviewing the model his changes regarding the short distances between door and bedside were added to the design."

The client questioned the level of safety regarding the location of the bed in the room. Jonas selected the EBD checklist from the sketch. The client read it and approved the design, as he could see that the sketch model had passed the evaluation done by the application. Another evaluation criteria that Jonas had forgotten were added, logistics, now the checklist showed a red indication at the logistics panel tree. It seemed as if the user representatives' comments and changes did not match with the evaluation of the programme. 7 peer reviewed EBD articles, supported that the distance relation between bed and doorway had to be extended for the staff to operate the utilities in the room. The meeting had to end and they decided that Jonas would update the model from the company office.

Back at the office Jonas continues his work on the bedroom. His boss interrupts him. Johanne took a day of absence due to illness and is too sick to work from home, but have left instructions. Jonas will have to finish her presentation material for tomorrow. Jonas opens Johannes project and can see that she has left him instructions from her laptop at home. He continues to work in the model.

"05.00pm: At home at last. Claus told me about a new open source tool developed for designer of high-speed trains that have some great surface relaxation algorithm. Will see if I can use this to develop the window shingles aggregation for the cafeteria room of the House of psychiatry that we start next week. Have agreed with the boss to work from home tomorrow."

Jonas has special interest in finding applications from other industries and uses them in his own creative exploration. Aside his work at the company he has extended his skill in design programming. He is part of a larger community of architects and designers and they share the benefits of various programs and tools. Many interesting designs have been developed and shared in that forum that Jonas has been able to integrate at work. His boss is very interested in the novel designs and multiple complex variations that he sometimes presents. She has promised him to be design manager of the next project at the company. Jonas will work from home tomorrow since he is ahead of the production and only online meetings are scheduled in the shared calendar.

4.5 Revised problem statement

Derived from the explorations on healthcare architecture, evidence based design, and software technologies the problem statement is revised to be able to specify the direction of the prototypes of this thesis.

The tools are still defined as parametric tools for architectural healthcare projects but specifically they are prototypes of functions and operations supporting the architect in the design phases of a project proposal.

Integrating the tools in the architectural practice has therefore become an important aspect. Surveys and user-reviews have been planned to direct the tools functionality towards the architects needs and workflow.

Revised problem statement

"How is a parametric application tool designed in Grasshopper, to support evidence-based design concepts in healthcare building projects?

"How are the application prototypes integrated in the design processes of an architectural practice?"

PROTO TYPE DESIGN

5.1 Strategy for prototype design

The prototypes are developed with emphasis on test and trial of the functions derived from the requirement analysis. The descriptions of the prototypes are based on their operational level. Focus is on the implementation of evidence-based knowledge in the actual programming in Grasshopper. The topic is safety with focus on floor plan and bedroom design of a hospital.

Main purpose

The main purpose of producing prototypes is to be able to evaluate the specific requirements of the method in a simulation of real architectural work practice.

The prototype development process cover a set of basic functions and operations and two main prototypes that each have specific foci and design theme. The basic functions have been integrated in the two main case prototypes.

Derived from the scenario models the following prototype goals have been chosen to work with:

+ Linkage between design issues and EBD information

+ Usage on different scale and detail level in projects

+ Weigh user participation through sketch and feedback

+ Ability to steer, control and maintain overview of goals and tasks

The two main criteria of methodological success is;

1) The effect that the prototypes will have in bringing EBD information into the design process

2) The architects' feedback on prototype possibilities and limitations according to their work process. The subject of reluctance as a direct result of the EBD information level and rigidness of designing in software is significant to obtain feedback upon.

Each of the basic functions follow a developments structure of 1) Initial investigations, 2) Requirements 3) Development 4) Feedback 5) Issues

Parametric definition

The prototypes consist of a number of different operations all of which has specific sets of parameters, definitions and relations to other parameters. The overall method of parametrical definition is by identifying following typologies and their relations; 1) driver (parameter) 2) driven (single parameter or set of parameters) and 3) constraining parameters (boundaries, limitations and conditional statements) [Kilian, 2006] The method is a rework of the Parametric Design Method [Architectural Affordances, 2008] developed by the author prior to this thesis. [Killian, A., 2006, Design exploration through bidirectional Modeling of constraints, MIT Press, Massachusetts]

Test and evaluation is conducted in the chapter [Evaluation]

5.2 Evidence based design data

The design of prototypes in this thesis is substantiated in evident data and research. The conditional statements that are used for calculation are drawn from collections of relevant and valid evidence based design material. This section is an elaboration of the translation of evidence based results into parametric geometry. The performed evaluation and assessment on behalf of EBD derived criteria are discussed.

Interpretation of data

Following is an example derived from the use of the same article and data source but within different fields of design research. Highlighted are the words and sentences that are found relevant for this thesis subject of patient safety and floor plan design:

Article reference

McKendrick, G. D., & Emond, R. T. (1976). Investigation of cross-infection in isolation wards of different design. Journal of Hygiene (London), 76(1), 23.

Roger Ulrich's review of research literature on evidence based health care design:

Providing single-bed rooms increases isolation capacity; facilitates filtration, ventilation, and airflow control (e.g., negative room pressurization); and by these well-established measures or mechanisms, it plays a key role in preventing a patient with an aerial spread infection from infecting others and protects immune compromised patients in nearby rooms from airborne pathogens. As might be expected, studies of cross-infection for contagious airborne diseases (such as influenza, TB, measles, and chickenpox) have revealed that placing patients in single rooms (Ben-Abraham et al., 2002), single-bed cubicles with partitions (Gardner, Court, Brocklebank, Downham, & Weightman, 1973), isolation rooms (Mulin et al., 1997), or rooms with fewer beds and more space between patients (McKendrick & Emond, 1976) is safer than housing them in multibed spaces with more patients.

The same reference (McKendrick & Emond, 1976) as used in Healing Architecture;

A mapping of the infection rate of airborne deceases at seven isolation rooms. The project was conducted for 5 years and consisted of daily registrations of the room condition and statement of measles (Varicell zoster virus) of the hospitalised patients. All examples are single bedroom, with varying plan solutions and the rooms distributed in different ways. The examinations reveal that the largest infection rate is at bedroom where ventilation goes through a shared corridor (infection through open door) Recommendation; small rooms, branched, arrival through air lock from corridor.

A section from the original evidence reference that the publications refer to;

Investigation of Cross-Infection in Isolation Wards of Different Design, (McKendrick & Emond, 1976)

From this study covering seven hospitals it would seem that the existing wards and isolation techniques afforded a high degree of protection with an incidence of cross-infection of 1-68% for varicella and 0.8% for measles. There was considerable variation between the hospital units, the largest discrepancy being for varicella, with 3-4 cases of cross-infection per 1000 patient/days in Hospital 1 compared with nil in Hospitals 3 and 5 (Table 4).

Table 4. *Relation between ward layout and cross-infection*

Hospital	Size of: Ward (beds)	Size of: Ward units (beds)	Corridor: Lateral	Corridor: Central	Corridor: Not enclosed	Ventilation into corridor	Cases of cross-infection per 1000 patient/days: Chicken pox	Cases of cross-infection per 1000 patient/days: Measles
1	26	26	+	+	−	+	3·4	1·0
2	20	5	+	−	−	−	0·9	0
3	15	5	+	−	+	−	0	0·7
4	28	28	+	+	−	+	2·2	2·3
5	15	15	−	+	−	−	0	0
6	28	28	+	+	−	+	1·2	1·5
7	24	24	+	−	−	−	2·0	1·0

Considering the different use and interpretation of the same data set, as exemplified above, it might pose an issue how to validate or rely in the data and the guidelines the different authors draw within their respective fields and mindset. It is up to the reader of the material to judge what is important for his/her assignment, which can be a tedious task for an architect during a creative work process.

In this thesis the mindset is that of the architectural designer, and here emphasis lie with the publication Healing Architecture, bridging between medical and healthcare research and architectural design.

Case of contradictions in the research biography

In a few cases the available material contradict. Following is an example of contradictions of research results regarding the number of sinks in the bedroom and the frequency of personnel hand washing:

Vernon, M. O., Trick, W. E., Welbel, S. F., Peterson, B. J., &

Weinstein, R. A. (2003). Adherence with hand hygiene: Does number of sinks matter? Infection Control and Hospital Epidemiology, 24(3), 224.

Research shows that the number of sinks per bed, as only precaution, does not have significant effect on the frequency of hand washing.

Kaplan, L. M., & McGuckin, M. (1986). Increasing handwashing compliance with more accessible sinks. Infection Control, 7(8), 408

Research show that the number and availability of sink has significant effect upon the frequency of hand washing.

Within these to opposite statements from Healing Architecture [Frandsen et al. ,2009] exist tacit questions and factors, regarding the highlighted words and their meaning. Also the data source from both references; how do they respond to each other, how were the tests performed and what factors could have been the reason for the different conclusions. This is beyond the scope of this thesis, but it is important to state the "danger" of being misled or confused in the use of data, when trying to create the most valid and reliable offset for the parameterisation of for instance the patient bedroom.

Validity and reliability

The EBD materials used in this project are reckoned valid and reliable for prototype use when referenced in Healing Architecture [Frandsen et al., 2009] and in A review of research literature in evidence-based design [Ulrich et al, 2009]. Using of singular research article is considered reliable if published and peer reviewed.

Judging and weighing

In cases where different data contradicts each other, a topic or where interpretations differ, the focus is on Healing Architecture. If not a part of the article review of Healing Architecture it is up to the author of this thesis to judge whether or not the data is of methodological relevance. Weighing the empirical material is also in this case up to the author. If done so, it will be stated in the report as a necessary source of error.

Translation into defined parameters and credit values

The EBD guidelines are translated from data results and guidelines into programmable parametric setups. The translation logic is based on 1) the selection of an EBD topic and the specific subtopic herein, 2) the selection of an overall task topic and the specific subtask herein.

Example

EBD Topic – Patient Safety

Subtopic, noise, infection, patient falls

Task topic -Bedroom design,

Subtask -Distance bed to bathroom, location of sink, amount of alcohol dispensers, and free area in the room

All relevant results and guidelines regarding keywords bedroom, bathroom, noise, infection, falls under the context of safety of patients are the basis for EBD references and criteria of assessment.

Each defined guideline or EBD rule opens a variety of sub questions. Sub questions are relational statements and conditions that have an effect on the topic-task evaluation. The prototype will gather these criteria for the user to decide whether or not to implement in the calculation, by simply toggling options on and off in the prototype.

If an EBD guideline is found significant it undergoes a process of parametrical definition. This is the location and definition in geometric space, the number of conditional statements to be fulfilled and an integer valued criteria connection from the specific guideline to the total assembly of all related criteria of that specific task.

Example

Topic, subtopic and task, subtask

Patient safety, patient falls – Bedroom, distance bed to bathroom,

Sub questions;

Is the room single or multi bed? Is bathroom en suite or shared? What is the material on the floor? Is there a hand railing to support the patient?

Relational parameters:

The value of an EBD criterion can be differentiated if it is related to other EBD criteria or topics. This can depend on the task and topic choices of the user and of the logic of the prototype. A criterion has its own credit value. This will be multiplied by a number of factors depending on the other relational criteria that have evident effect

The following exemplification shows the different relations between tasks; bedroom type and location of bed and topics; Safety and Relations [Frandsen et al., 2009] as well as different types of credit value assessment.

Example

EBD guideline:

Evidence show that the choice of single bedrooms in the design plan decrease infection rates among patients, increase sleeping time and restoration as a result of privacy but decrease the level of social relations to other patients (Ulrich et. al.)

Bedroom type

Single: credit value 5

Relational value in other EBD topics:

Safety, Infection rate; 1.1x(part sum)

Relations, Privacy; 1.1x (part sum)

Relations; Social; 0.9x(part sum)

Multiple bedroom

2 beds: credit value 0,5

4 beds: credit value 0,2

Bathroom

En suite: 3

Shared: 0.9

Floor material:

Corned vinyl: 1.0

Vinyl: 0.9

Carpet: 1; 0.9X(Infection rate increase)+1.1X(Noise reduction)

Handrail to bathroom:

Yes; 1

No; 0

The choice of one criterion might increase or decrease the level of another. The example show that relations to other categories under different topics are significant and worth investigating. The credit value for the immediate criteria is named primary. The value added to or from a relational parameter is named secondary value. The secondary value is part of an expression multiplying more or less to the specific criterions primary value. This is done in another part of the calculation matrix.

Example

Single bedroom; primary credit value; X= 5

Secondary values F(x)=1.1(Infection) F(x)=1.1(Privacy) F(x)=0.9(Social)

The resulting sum from the additional criteria is added as part of a larger sum matrix for the whole prototype.

The relational calculation goes both ways. The single bedroom value is affected by factors from Safety and Relations parameters, but the bedroom criterion itself affect the criteria specified within topics Safety and Relations.

5.3 Parametrical definitions

Object related criteria

Some of the conditional statements are linked to the geometry within the model.

Object related criteria are defined by either Function component F(Xn) or a VB.Net component, depending of the number of input (X,Y,Z) and the character of conditions, e.g. scripted subs, functions, loops and conditional statements.

Using the Slider component, entering value or manually move geometry in the Rhino viewport affect change in geometry and conditions. When conditions are violated they are considered false and does not produce output, hence tribute to the sum.

Check box criteria are related to the subtopic and sub-questions of the main topic. They are defined by a Boolean Toggle component that if toggled true a value is sent to the sum module as part of the EBD assessment.

Most of the scores will have the value of 1 since that is the value of a Boolean true statement, which is widely used in the prototype setup.

Example: Distance from bed to bathroom

EBD reference (as guideline); Evidence show that distances above 7 meters from bedside to bathroom door increases the chance of patient falls and injuries and therefore should be avoided [NHS Estates, 2005]

This guideline in translated into following parameters:

Bedside mid point (X1,Y1), Bath room door mid point (X2,Y2)

Line component, Line length, F(x) Component with expression (X<=7), List component, Mass addition component.

As scripted VB.Net component, the following conditional statement would be written

If x <= 7 Then, x = 1, Else x = 0, End If

Processing the parameters

The parameters from the example above are either processed by an expression in the Function components, a Boolean value from a toggle or conditional statement or a value from a conditional statement within a script.

If the users design proposal fulfils the conditional statements, the coherent input values are sent to a sum list.

Criteria that are not met send no value further.

As the user alters the definitions or the geometry conditions and change and results are updated.

Value and Addition

Giving each individual evidence based design criteria within the scripted prototype a value affects the overall outcome, the assessment of the overall performance score of the designer's proposition. There are different mathematical statistical models of calculating the percentage, the Gaussian distribution and similar results. This thesis uses the same accreditation model as DDKM and Green Guide for Health Care by assigning each criterion a credibility value, a double that can be added the sum of all EBD criteria.

The level of influence by each criterion on the overall EBD topic is considered when adding values to the sum list.

It would be misguiding to let the single bedroom option have the same value as the criteria of the location of an additional alcoholic gel dispenser in the bedroom.

Where relevant material have been inadequate the author have proceeded as best seen fit in defining the criterion values

Supplements for EBD with parametrical issues

The various sources for evidence based research materials are in this project supplemented by reliable facts derived from studies in material produced by architectural and governmental consultants. This is the case when translating geometry into scale and distances where evidence does not exist due to the novelty of this project. In cases that no valid guide or reference is found, best practice or logic derivations are implemented to complete the prototypes.

5.4 User interface

The prototypes are developed specifically for active engagement between software and the user. The interpretations, actions and selections by the user depend on the user interface design. In order to prevent reluctance and confusing the design of the user interface of the prototypes are important in order to function optimal.

The prototypes are designed with reference to the 8 golden rules of interface design [Schneiderman et al., 2005, p.74]

1. Strive for consistency

2. Cater to universal usability

3. Offer informative feedback

4. Design dialogs to yield closure

5. Prevent errors

6. Permit easy reversal of actions

7. Support internal locus of control

8. Reduce short-term memory load

Rules 1, 3 and 6 have had the most influence in designing the prototypes.

When striving for consistency in the prototypes the user will spend less time decoding the definitions interface options. The consistency is obtained by always arranging the definition components in the same order and place.

Input parameters are grouped and located to the left and the relational output next to the right.

In case a more thorough explanation of procedural steps is needed, the explanatory panels will be ordered by number from top to bottom with the respective input and output box within close proximity.

Being prototypes the definitions are rich in explanatory material within the canvas of grasshopper. The panels are used to guide the user of the operations. Feedback is provided at each action the user does in either geometry definition in the Rhino viewport or the output string in the Grasshopper panel. If the users actions violate the statements made in the script the immediate real time feed back is provided by text and colour of geometry.

The reversal of actions is provided within the interface of Grasshopper by using the undo function and common keyboard shortcuts. When saving the definition the user will have to save as new file in order not to overwrite, thus damaging the setup of the prototype.

5.5 Basic EBD modules

The structure of the elaborations on the basic EBD modules provides an understanding of the prototypes functionality and assessment.

The basic modules are 1) EBD reference module and 2) EBD assessment module

EBD Reference module

Purpose

Getting the information relevant for the task when needed is considered important. But the method cannot rely solely on what the user knows, and when or where to seek information. This requires a module that both provide mandatory and additional information regarding the task in progress.

The reference module display different conditional content

Notes; a list of notes and guidelines relevant to the task

Alerts; a list of error specification

References; a list of references, information, articles

Initial investigations

The information that the module contains is derived from the references of Healing Architecture, 2009.

The module consist of both publication references, EBD guidelines to help with the object design as well a list of relations to other subjects for further investigations.

Requirements and definitions

The modules rely on a database of texts that can be written to Grasshopper. These texts are simple text files that are loaded into Grasshopper.

The models can be turned on an off respecting the users willingness of having the feed of information.

The component is connected to a assessment module and scripted to react upon design issues of the users actions.

Development

The module consist of three “Read File” components that are linked together each with a ”Boolean Toggle” letting the user click the output on and of. The path of the components is pointing to a selected folder on the hard drive containing the text files. A “VB.Net component” manages the input parameters from the topic specific modules linking to the geometry in the model. If conditional statements are not met the script will perform an operation referring to the specific EBD lists.

Feedback

The feedback of the EBD reference module is displayed as text inside panels in the Grasshopper canvas. Additional feedback is linked to the colouring of objects and geometry within the model creating a visual link between text component and object model. The feedback panel is connected to a “Receiver” button that receives the text string from the component containing the text.

Additional, the panel text can be places at point of the situation inside the geometry, but that is avoided due to confusion.

Issues

Updating the text file content has to be done manually but serving as a prototype solving this issue during this thesis is not of importance.

Selecting valid reference materials as foundation for evidence requires continuous update and research on the topics. For the sake of the prototype present references derived from Healing Architecture are used.

EBD Assessment module

Purpose

The assessment module is the control module of either all the prototype conditional statements or a selected group of statements. Each statement refers to a topic of EBD, e.g. Safety. The purpose is to create a container of all the values relevant of the specific prototype topic in order to have a measurable assessment of how well a set of criteria have been met.

Initial investigations

The conditional statements are derived from the references of Healing Architecture. The assessment method is furthermore related to the accreditation value method of the GGHC and DDKM [Appendix01], by adding the number of credit values to a sum list and performing a mean calculation based on the relative percentage of the total set of criteria.

Requirements and Definition

The module for this operation requires a "VB.Net" component to manage all the input. The number of input depends of the number of conditions that are part of the prototype. The output data is the processed result of the inputs made. The processing is done in scripted loops so that the right number of statements results in right value of output.

Development

The definition consists of a number of VB.Net modules depending of the amount of relational inputs. The inputs are Boolean, integers and doubles and conditional statements are written inside the script to match each number of input. Depending of the statement e.g. the Boolean value of either 0 or 1 is added to a list. 0 is for not fulfilling the statement, 1 is for fulfilling the statement. This list is outputted to a panel that display the sum of values and the EBD credit value.

Feedback

The output is an addition to a list of integer values. The total sum of the list is calculated and the percentage value of the conditional fulfilment is displayed in a panel. The user is informed of the score by text and visual colouring of objects on the canvas.

Issues

The handling of many outputs poses an issue of the overall readability of the prototype. The link to the correct component holding the reference text that coheres to the assessment score is to some extent inflexible. It reads the whole string and not just the individual line related to the missing or failed input.

Summary on basic functions

Basic functions as calculation and scripting constructions, information, communication and visual feedback are embedded within the prototypes and therefore not exemplified in this section.

The level of feedback needed depends of the design task. If it is fast mock-ups in the early design phase, the colouring of objects as visual indicators is considered important. If the task requires more in-depth design exploration texted hints and references are the apparent choice.

5.6 Prototype; Bedroom design

Prototype strategy

The prototype is designed to support the architect in the sketching and detailing process.

The foci is on

+ Linkage between design issues and EBD information

+ Weigh user participation through sketch and feedback

Design tasks

+ Selecting or importing objects according to room specifications

+ Arrangement of objects

+ Selection of parameters for the rooms' specification

Prototype functions

+ Calculation of free space, room size

+ Managing ebd information regarding the choices made

+ Calculate EBD credit value

EBD functions under the topic of safety

+ Size of room and free space for optimal work routines

+ Minimal space for utilities

+ Infection control

+ Visibility and distance to nursing station

+ Distance to bathroom

Other functions

+ Participation of user representatives in planning of the bedroom

+ Documentation of design criteria

+ Design process using the prototype

Detailing the bedrooms organisation, logistics and material choices offers the architect the possibility to design a room with optimal patient safety parameters.

The bedroom is either loaded into grasshopper or the objects are rearranged right away. A list of objects is available for selection, each parametrically connected to the other. The prototype support both 2D and 3D objects in the planning.

The function of analysing the distance and visibility to the nearest nurse station contributes to the evaluation and assessment of the level of patient safety of the design proposal.

The architect receives an immediate EBD credit score and a list of fulfilment and error notifications on behalf of the design decisions. This serves as documentation of the design process and expected impact on health care design.

Initial investigations

Interviews with Heine Overby, manager of production and building, Laila Bodsgaard, Security manager and Louise Weikop, Quality coordinator at Aalborg Hospital have provided with information on applied patient safety in hospitals.

Analysis of the bedrooms at the old and the new parts of Aalborg Sygehus have helped clarify the differences needed to improve the safety in the environment around the patients.

The empirical and qualitative data have contributed to the parametric setup and scripting of the prototype.

Literature usage involve:

+ Den gode sengestue, 2003, Vejle amt, Denmark

+ Det gode badeværelse, 2001, Vejle amt, Denmark

+ Ward layouts with single rooms and space for flexibilityNHS Estates, 2005

+ Frandsen, A.K. et al. ,2009, Helende arkitektur, Danske Regioner, Denmark

+ Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H. B., Choi, Y. S., et al. (2008). A review of the research literature on evidence-based healthcare design. HERD, 1(3), 61.

Medicinerhuset

Bedroom investigations

Following are the investigations of improvements regarding patient safety in the bedrooms at Medicinerhuset.

+ Standardised oxygen and supply outlets
+ Hygiene improved surfaces around appliances.
+ Alarm buttons at the bed, the table and the toilet
+ Secure windows to prevent suicide
+ Touch free sinks
+ Nurse finder technology
+ Grained floor material in the bathroom to prevent falls
+ Fabrics in the bedroom are washable at 80 degrees
+ Electric traising in the water pipes prevent Legionella decease.

The focus on hygiene and standardised work routines improves the overall level of patient safety at Medicinerhuset.

Floor plan investigations

The bedrooms at Medicinerhuset have been planned by a gross/net factor of 2,3, which is above the recommendations [Møller, C.F., 2008]

The bedrooms have an average size of 25,8 m2 which is below the recommended size [Vejle Amt, 2003] This indicates that the additional amount of m2 have been allocated as flexible square meters for future development

One decentralised nursing station per ward. One ward holds 13 double bedrooms. The total number of beds is 26.

The overall level of patient safety at Medicinerhuset is in line with the guidelines [Ulrich et. al., 2008]. The bedroom sizes are smaller than recommended (33 -35.5 m2) [Vejle Amt, 2003] and the optimal free spaces are not satisfied. The accreditation results regarding the patient and personnel satisfaction show that meeting physical standards does not reflect good health care environment alone. The extra value must come from other topics such as work routine, company moral and aesthetics. For now the thesis still focus on patient safety for the design of the prototypes.

Bedroom module

Purpose

The topic of the tool is patient safety and how the near environment of the patient can contribute to a more safe in-house hospital stay. The prototype is based on parameters and evidence regarding the organisation of the patient bed room.

Definition

Evidence based research indicate that the organisation and size of a bedroom and the objects that fill it, contribute to the level of safety, that being levels of hygiene infections, patient and staff injury and infection related deaths.[Ulrich et. al., 2008]

There are 2 entry paths; 1) The application requires no detailed layout of at bed room CAD drawing prior to the use of the tool and 2) The architect load a already defined outline of the bedroom into the prototype for further detailing and assessment

Development

A list of procedural task-descriptions guides the architect through the use of the tool.

The architect selects the objects that are to be implemented in the room and relocates them accordingly.

Once the location of the respective objects is specified the script calculates the objects midpoint and the distance between objects to determine the spatial relations and object-free zones.

Each conditional criterion is assessed and sent to one of the evaluation scripted lists.

Driver

The objects midpoint

The number of objects

The parameters chosen for evaluation

Driven

The intersections between objects

The conflict list

Constraints

Bedroom size boundaries

The EBD accreditation percentage

Feedback

A graphical representation of the bedroom room is visually present at all time during the evaluation.

Relational zones operated by the objects are defined by a surface plane of grey colour. Intersections between objects are coloured red and a alert message is executed in the alert box.

Each red indicator is followed by a description of the error and a list of references where additional information can be found

Note panel

The main part of injuries from falls happen from the bed or around the bed at night, with less surveillance and nurse contact. The locations of nursing station and alarm systems can have great influence on patient falls and injuries.

van Leeuwen, M., Bennett, L., West, S., Wiles, V., & Grasso, J. (2001). Patient falls from bed and the role of bedrails in the acute care setting. Australian Journal of Advanced Nursing, 19(2), 8.

Objects

The following objects should be present in the bedroom;

1 Bed

1 Bed table

1 Lounge Chair

1 Small table

1 Table chair

1 Closet as wardrobe

1 Supply closet

1 Sink *

1 Alarm call button for every patient station**

1-2 Alcoholic gel dispensers

1 window

1 bathroom door

* If the bathroom is shared with other bedrooms the sink should be patient ready. Look up in the reference box

**Patient stations are bed, lounge chair, table chair

[Den gode sengestue, 2003, Vejle amt, Denmark]

Bed; Passage at bed end; 100 cm, Work space 190x250 cm, Workspace 90cmx2/3 of bed length

Sink; Workspace D 200 cm

Lounge chair; Workspace D 200 cm

Table; Free space 90x75 cm

Bedroom door; 315x140 cm on bed side, 260x260cm on ward side

Bathroom door; 165x165 cm on bed side, 190x250cm on bathroom side*

*depending on the appliances in the bathroom

Small Table; 70x80cm

Table chair; 50x50 cm

Closet; 45x60cm

Supply closet; 80x60cm

Sink; 60x55cm

Bedroom door; 10x130cm (double door 90/40 cm)

Window; 10x100cm

Alarm Call; N/A

Door to bathroom; 10x90cm

Ref panel

Den gode sengestue, 2003, Vejle amt, Denmark

Det gode badeværelse, 2001, Vejle amt, Denmark

Ward layouts with single rooms and space

for flexibility, NHS Estates, 2005

Frandsen, A.K. et al. , 2009, Helende arkitektur, Danske Regioner, Denmark

Ulrich, R. S., Zimring, C., Zhu, X., DuBose, J., Seo, H. B.,

Choi, Y. S., et al. (2008). A review of the research literature on

evidence-based healthcare design. HERD, 1(3), 61.

Alert panel

CONFLICT; Alarm buttons INSUFFICIANT

CONFLICT; Alcoholic gel dispensers INSUFFICIANT

CONFLICT; Bed intersect with other objects

CONFLICT; Sink intersect with other objects

CONFLICT; Bed room door intersect with other objects

Issues

The tool needs updating if another object class than defined in grasshopper is used. The definition have difficulties identifying complex mesh object and have to be repaired before they can be input.

By extending this tool to encompass the full capabilities of 3D models, elements as acoustics, location of ventilation, levels of illuminance might also be used.

By developing a module in grasshopper that lets the designer provide with own metadata and definition new objects can be used in the script without having to rewrite the whole application.

Nurse station module

Purpose

The presence of near by nursing stations result in more contact with patients and faster respond time in critical situations

Development

The module consists of modules to determine the midpoint and height of the patient bed. The distance from the bed to the door to the nursing stations is calculated. The intersection between objects in line of sight from the nursing station indicates that the visibility of the patient in the bedroom is compromised.

Driver

Midpoint of nursing station and bed in patient room

Driven

The vector between the two or more points

Constraints

The distance and the intersecting objects

Feedback

If intersections in the line of sight occur the intersection line is coloured red and a text based conflict is listed in the conflict box

If the distance between nursing station and bedroom is above 15 meters the conflict notifier is executed.

Issues

The definition does not take into account windows towards wards. These objects will intersect with the line of sight. The windows will have to be subtracted from the geometry before assessment.

EBD criteria selection module

Purpose

This module offers specific design choices regarding the non-measurable geometric organisation of the bedroom. The criteria are related to material and utility choices that have impact on patient safety.

Development

The module consists of at VB.Net scripting module where the number and value of input is calculated inside the script. A value credit for the overall selections is processed to the EBD credit list as part of the overall EBD credit score.

Feedback

The feedback from this module is a display of the EBD credit score in the EBD score box

The selections made are updated to the Parameter list

Issues

In case additional criteria are added to the VB.Net module the number of inputs and outputs, conditional statement and expressions of need to be updated.

Implementation examples of existing floor plans

The bedroom module is used on various bedroom plans, medicinerhuset, and Thisted.

5.7 Prototype; Floor plan design

Prototype strategy

The prototype is designed to support the architect in the initial sketching process. Experiences from the "day in the life" scenario at Friis & Moltke have been used to determine the following subjects of prototype focus:

+ Usage on different scale and detail level in projects

+ Ability to steer, control and maintain overview of goals and tasks

The design prerequisites are the architects initial sketch plan, and the overall demands regarding area size and facility capacity from the building programme.

The prototype provides information and guidelines of the explicit distribution of square meters of the floor plan. The increase in detail from sketch to floor plan is based on informed design decisions from evidence based knowledge.

Based on number of functions, bedrooms and area, the overall space needs to be distributed to make sure that the building developers demands are met within the architectural concept.

Design tasks

+ Importing sketch work

+ Floor plan design through digital sketch

+ Distribution of basic facility modules

Prototype functions

+ Managing input geometry

+ Calculation of area, bedroom count, floor levels, size of bedrooms on initial and updated geometry

+ Inform the user on evidence based design knowledge

+ Alert the user when overstepping geometrical parameters and boundaries

+ List references and notes to evidence based design knowledge

EBD functions under the topic of safety

+ Minimal functional space requirements

+ Room modules sizes are within boundaries set by EBD knowledge.

+ Building plan complexity and distances

Other functions

+ Meet the restrictions of the building program

Design process using the prototype

The input sliders cover basic specifications from the building program. Area size, bed count, the size of bedroom modules and the number of floor are part of a calculation matrix. The resulting number of modules based on recommendations on gross/net factor for medical wards [Møller, C.F. 2008]

The number of modules are distributed in the Rhino view for the architect to rearrange to get an idea of the project size and possibilities. The next level of detail is choosing the number and size of bedroom modules from the available layer in Rhino. Rearranging and combining them according to the sketch module arrangement lets the architect defined ward structures, hospital streets and bedroom configurations.

The evidence based function of the prototype is furthered by introducing the calculation of the Interconnection density number (ICD) of the floor plan and the distances between individual bedroom to the hospital street. This is to point our issues regarding the floor plan design.

The use of the prototype ends with the architects approved floor plan. The plan is considered approved if all evidence based design criteria are fulfilled.

Diagram of the process of using the prototype, showing the process of the use of the prototype, from loading the sketch to the final plan, end with a couple of plan variations that live up to the EBD demands.

Initial investigations

Arguments regarding the EBD input for the prototype have been established by reviewing the literature of [Frandsen et al. 2009] [NHS Estates, 2008] and [O'Neill, M, 1991a & 1991b]

Empirical studies have been performed at the Medicinerhus to investigate in the complexity of the floor plan and the nurse travel distances.

Interviews with staff at Medicinerhuset have clarified significant details regarding the decrease in patient treatment as result of long travel distances.

Medicinerhuset

The calculated ICD number for a floor in the Medicinerhus is calculated to be 2,3

The longest distance from bedroom door to nursing station is 40,1 meters.

The longest distance to the hospital street connection is 53,3 meters. The distances are within the recommendations regarding complexity of floor plan levels [NSH Estates, 2005].

In order to help with navigation specific information stands have been arranged throughout the building.

The Halls or atria with open space that reach beyond multiple floors serves both as navigation identifiers and complexity points.

ICD number module

Purpose

The purpose of this tool is to evaluate specific criteria within the topic of patient safety regarding the complexity of the floor plan.

Definition

The topographical complexity of the floor plan is evaluated and the ICD value is determined. The resulting value predicts the number of possible path connections and choice points in the floor plan and is part of the assessment of patient safety.

Derived from EBD research material Evaluation of a conceptual model of architectural legibility [O'Neill, 1991a] the total ICD number (Y) is in this calculation to be within the following boundaries 2,40 < Y>2,54 to fulfil the EBD criteria of the ICD number.

Development

The definition is designed to define a number of choice points (path connections) and evaluate how many choice paths are available thereby assessing the complexity of the floor plan. Each choice point is given a score from 1 to X, X being the maximum number of possible paths, and the mean score from all the choice points of the floor plan is returned as a value, Double.

The input is the floor plan, this being a 2D CAD drawing. The user places a point where the wards intersect. From each point, lines are emitted in 4 directions (every 90 degrees). For each intersection between wall curves and choice point line, the choice point receives a value of 1. The sum per choice point X is then added the sum of the remaining choice points X^n. The final sum, Y=sumX^n is divided by number of choice points N. The result is shown as a value in the panel box.

Driver

Location of choice points 1, 2 and 3

Driven

Intersection lines from each choice points in all directions to wall curves

Constraints

Wall curves as boundaries for intersection

Function F(x), 2,40 < Y>2,54 with return value 0 or 1

Colour gradient; Green-Yellow-Red

Feedback

Upon using the application and evaluating the floor plan the user is given a ICD score and a visual feedback in colour that tell whether or not the proposed floor plan meet the chosen criteria of patient safety.

The coloured choice points let the user examine where in the floor plan the problematic choice points are.

ICD number and colour

ICD=2, Green

ICD=3, Yellow

ICD=4+, Red

Following feedback is provided to enlighten the user regarding the state of the floor plan evaluation:

Note panel

Evidence prove that there is a clear relation between the complexity of the floor plan measured by ICD number as well as time consumption, backtracking and the number of wrong choices. [Frandsen et al., 2009]

Ref panel

Frandsen, A.K. et al. ,2009, Helende arkitektur, Danske Regioner, Denmark

O'Neill, M. J. (1991a). Evaluation of a conceptual model of architectural legibility. Environment & Behavior, 23(3), 259.

O'Neill, M. J. (1991b). Effects of signage and floor-plan configuration on wayfinding accuracy. Environment & Behavior, 23(5), 553.

Lawson, B., & Phiri, M.(2003). The architectural healthcare environment and its effect on patient health outcomes. NHS Estates

Alert panel

ALERT! ICD number of the floor plan should be 2,40<Y>2,54 in order for way finding to be optimal. More information is found in the references in the ref box

Issues

The tools need the user to actively select points and wall curves which can be tedious when changing the design of the floor plan.

In case the same choice point have more than 4 possible path directions the tool will have to be adjusted.

Distance module

Purpose

This function determines the distance between each bedroom and to the doorway from the hospital street. The hospital street is the hallway connecting the individual bedroom wards. Derived from the reference Ward layouts With Single rooms And space For flexibility NHS Estates, 2005 the maximum distance is set to 6000 cm. Distances above that limit indicate that nurse travelling and staff time consumption pose an issue regarding the treatment of the individual patient.

Development

Each bedroom object consists of wall curves, object curves and door curves. From the midpoint of the door rays in the X,Y plane is extended. The same procedure is done for the doorway from the ward. Intersection lines between the doors are calculated and the length vector added. A VB.Net script evaluates the distance. If found above 6000 cm the criteria has failed.

Driver

Driver01: Bedroom doorway midpoint

Driver02: Hospital street doorway midpoint

Driven

Driven A: The vector length (measured distance) between driver01 and driver02

Function01: Function (X) with return value (A) = 0 or 1

Constraints

Constraints: Expression parameters within function01. Boundaries; 1>X<6000 (60 m) Conditional statement; If X > LimitX Then A= 0, Else A=1, End If

Output01: List of text holding text strings sorted by type (alert or note) depending on output of Function01

Feedback

Feedback is done by text in the EBD boxes. A colour gradient is set for the custom preview module and connected to the door geometry and the extension lines. If the distance is within 6000 cm the colour of the objects is green. If not the colour is red and the alert indicator is executed.

When the user changes the location of the bedroom objects the distance is real time updated.

Note panel

The maximum distance from the bedroom to the hospital street should be less than 60 meters. Distances above that limit increases staff walking distances, confusing visitors and specialists from other departments and time spent on transportation. The effects are reduced treatment time and reduced number of daily routine check compromising the treatment and safety of the patient as well as the social relations. [NHS Estates, 2005, p.15]

REF panel

NHS Estates. (2005). Ward layouts with single rooms and space

for flexibility, NHS Estates, p.15

Ref panel

Den gode sengestue, 2003, Vejle amt, Denmark

Ward layouts With Single rooms and space For flexibility NHS Estates, 2005

Frandsen, A.K.et al. ,2009, Helende arkitektur, Danske Regioner, Denmark

Ulrich, R.S., Zimring, C., Zhu, X., DuBose, J., Seo, H.B.,Choi, Y.S., et al.(2008). A review Of the research literature On evidence-based healthcare design. HERD,1(3), 61

Alert panel

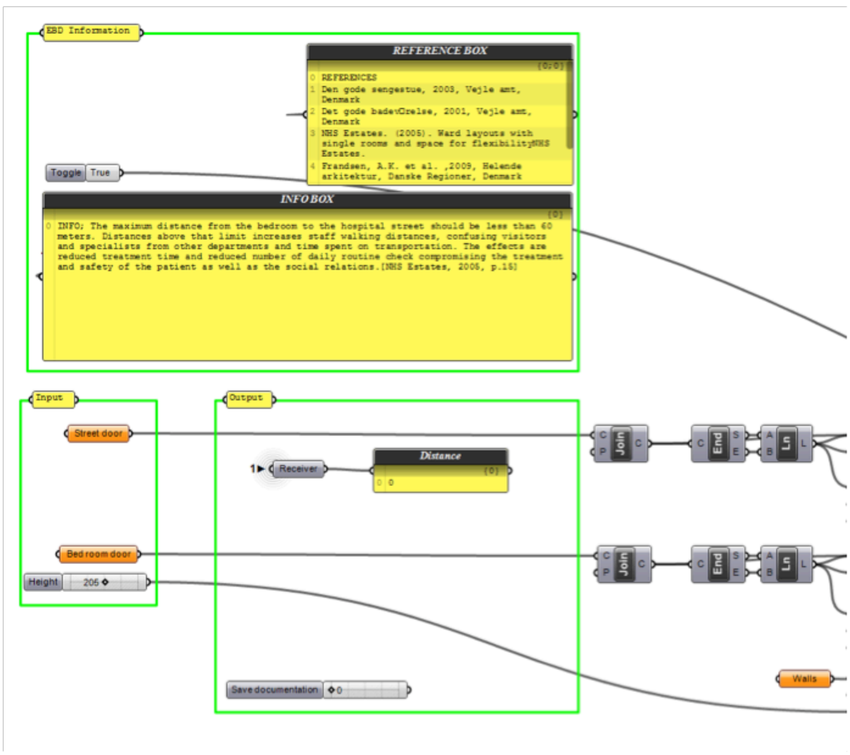
ALERT! Distance from hospital street to bedroom is above 6000 cm. If you reduce the distance to fit the maximum of 6000 cm, staff will spend less time of walking the long distance and thus have more time for patient care. More information is found in the references in the ref box

Issues

The order in which the geometry of the wall boundaries and the bedroom door are selected is important when multiple distances are calculated. The user must alter the List Item module of each component in order to get the right distance.

Implementation examples of existing floor plans

The functionality of the prototype have been tested on existing hospital layouts throughout the development phase.



EVALU ATION

THE EVALUATIONS OF THE PROTOTYPES SERVE TO IDENTIFY STRENGTHS AND WEAKNESSES REGARDING POSSIBLE FUTURE IMPLEMENTATION DEVELOPMENTS. RESULTS ARE OBTAINED THROUGH A USER REVIEW CONDUCTED THOUGH A SURVEY AND A QUESTIONNAIRE. THE EVALUATION RESULTS ARE USED TO REFLECT UPON THE PRODUCT PERFORMANCE OF THE PROTOTYPES.

6.1 Prototype evaluation

Being designed to support architectural design practice the prototypes are evaluated by a number of test subjects within the field of architecture and health care design.

The survey method is introduced as evaluation of the usage and functionality of the tool prototypes. The results are used to indicate issues and suggest improvements for future design iterations exceeding this project. The test subjects of the survey are the same group that formed the respondents of survey 01 developing the scenarios. This fact is considered to strengthen the design process with respect to the fact that the respondents might be biased by their experience from survey 01 thus compromising the objectivity of the evaluation in survey02. This is accepted as a source of error in this thesis.

Investigations cover the following subjects:

EBD use in the prototype

+ Visibility of the EBD references (hidden, tacit, visible)

+ Implementation of EBD in design

+ Integration of own experience

+ Progression curve, confidence with information

Designing in the tool

+ Integration and implementation in work practice

+ Freedom of choice versus specific number of possibilities

+ Level of supporting interface regarding operations

Ideas for further development

+ Operations and functionality

+ User interface, errors, feedback

+ Evidence-based knowledge integration

+ Grasshopper functionality, BIM perspective

User review of the prototypes

Purpose

The main purpose of conducting the user review is to provide
+ Indications of the users understanding of the tool and its purpose.

+ Review of the usability regarding evidence-based design of the tool.

+ Identify problematic areas and issues, EBD- and application-wise within the tool to be used for development.

The survey is furthermore used to assess the effect to which the prototypes integrate evidence-based knowledge in the design process.

This is obtained through a participation survey. [Methodology, pXX]

Experience evaluation scheme

As part of the review the respondents' fill in a list of self-assessment questions related to evidence-based knowledge of patient safety. Depending of the exercise the user is asked to assess his/her immediate level of experience within 1) Plan prototype; distance, complexity, area disposition and orientation, and 2) Bedroom prototype; Infection, Interior, Falls and injuries. The method is introduced to be able to assess if a progression in the designer's confidence with evidence-based knowledge through the use of the prototype is present.

Method

The survey is conducted as a user review with emphasis on a cognitive walkthrough of the users to test the overall usability and functionality of the tools. [Plaisant & Sneiderman, 2005, p. 142]

Throughout the survey respondents are provided with a structured assignment. The assignments are digital sketching using the plan prototype and detailing a bedroom using the Bedroom prototype. [CD, Survey02]

The users are guided through the use of the prototypes and the interviewee is present at the execution of the user review.

The survey consists of four phases: 1) prototype presentation, 2) user test, 3) questionnaire and 4) evaluation.

The survey is tested through a pilot survey on four students of architecture to improve the survey methodology. Two of the students participated in survey01. Two questionnaires were handed in after the pilot survey.

The results from the test survey lead to changes in the presentation form of the survey as well as exclusion of the evidence-based experience assessment scheme.

The final survey at the architectural company Friis & Moltke had one participant and lasted approximately ninety minutes. One questionnaire was handed in after the survey. The respondent had also participated in survey01.

Questionnaire

As part of the survey a questionnaire is introduced as documentation. The purpose of using a written questionnaire is to get concise feedback on specific subjects. To strive for consistency the questions, the topics and response options are designed with short precise formulations. The number of options is within 2-6 categories rated from low to high level of agreement (depending the question) with checkboxes from left to right. [Frary, R.B. 1996] To ensure a high level of completion users are given "grey area" options in case they do not understand, agree or even disagree to a given question. This ensures the chance of a higher success rate among the participants. The users are given comment boxes for each of the prototype evaluations with the possibility of adding information regarding issues or suggestions of further development areas.

The questionnaire is directed towards specific investigations in the two prototypes. Additional personal data is used for comparison among user responses and to be able to use method triangulation in the summary of the evaluation.

Following are the specific task-related goals that the user is asked to evaluate upon:

Specific goals as evaluated through the questionnaire

Configuration of the prototypes

a) Launch of the application

b) Loading of geometrical objects

c) Configuration of initial tool specific parameters

d) Choice of evaluative functions

Plan prototype

+ Choosing the polyline of the sketch

+ Placing connection points in the plan

+ Bedroom prototype

+ Choosing the bed room polyline

+ Choosing object types

+ Placing and relocating objects

Modification of the functionality

a) Choice of the parameters

b) Alterations of parameters

Plan prototype

+ Changing a points locations and value

+ Modification of object location, adding new objects to the definition

+ Toggle hints and references on and off

Bedroom prototype

+ Changing the geometry of objects

+ Changing the location of objects

+ Toggle hints on and off

Interpreting the results

a) Reading of values and colours

b) Further interpretation of results

c) Change in design proposal

d) Use of results in design decisions

Plan prototype

+ Reading of connection points (red is negative, green is positive)

+ Reading of references and ICD number

+ Reading of hints

Bedroom prototype

+ Reading of zones and issues (red is negative, green is positive)

+ Reading of distance between objects

+ Reading of references to literature

+ Reading of criteria fulfilment score

+ Reading of hints

6.2 Learning from the survey

Statements from both test and user group are used to contemplate the evaluation of the prototypes. Questionnaire answers and statements from the feedback discussion at Friis & Moltke are combined and analysed.

General

Due to problems with scheduling the survey the number of respondents decreased to encompass 4 students as test group and 1 respondent as architectural user representative.

The results of the survey are part derivations from the feedback during the survey and part from the questionnaire. The feedback critique is available for listening on the attached CD-ROM [CD, Survey02]

The initial offset was to be able to use the questionnaire data as an empirical valid and reliable method. This is not considered possible due to the number of respondents. The results from the review and feedback situation are used as indicators of faults, issues and possible directions for further development within the frame of the thesis. A scientific foundation for a reliable statement regarding the expectations of an EBD tool implementation in professional architectural practice is not present at the moment of writing due to the insufficient empirical data.

Feedback

Basic functions

Regarding the understanding of the tool the users had no difficulty reading the purposefulness of the tool. The interface though was found confusing due to the many inputs and outputs.

The benefit from the prototypes was found to range from average to extensive.

The evidence-based information in the panels of both prototypes were found relevant but was not used to their full extent due to the many tasks and input-output functions which created some confusion.

In order to fit the practical workflow of the architect more detail in the prototypes are needed.

Plan prototype

The 2D sketching concept was found less important. The calculation of bedroom sizes and module arrangement were found useful

The prototype creates a connection between calculations and CAD drawing which is normally two separated tasks. This was found useful.

Bedroom prototype

The bedroom prototype was found to display functions that were directly applicable in the actual work-practice of the architect. The selections and assessment of evidence-based design criteria were found important.

The organisation of the bedroom was found very useful.

The visibility function and sight-line module need more development in order to give the impression of integration in the design plan.

The real-time feedback from the assessment module was found supportive.

The future development was found to be emphasised on evidence based concepts on sound, air and light.

Being able to create a evidence-based checklist and get fast reliable feedback was found useful.

Questionnaire results

The survey answers are listed in the diagram. Answers that could not be part of the scheme are available in the appendix [A05_Survey02].

Plan prototype

1. Configuration of the prototypes

The plan prototype was found easy to configure.

2. Modification of the functionality

Modifying the parameters and the functions of the plan prototype posed a little difficult when the modules had to be rearranged. Also one respondent received erroneous statements during the task.

3. Interpreting the results

The feedback from the actions in the Rhino view was found easy. The results from the connection between computer CAD drawing and sketch material was found less relevant.

Bedroom prototype

1. Configuration of the prototypes

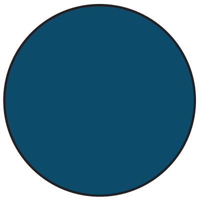
The bedroom prototype was found somewhat easy and somewhat hard for the respondents.

2. Modification of the functionality

The bedroom prototype was found confusing because of the many options and information boxes in the Grasshopper view. The assessment of the overall modification level is easy to somewhat hard.

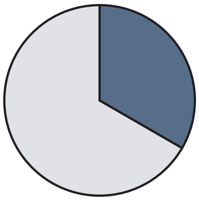
3. Interpreting the results

Reading the intersection lines and resulting feedback messages in the bedroom was found easy. Choosing the EBD foci was considered a valuable option.



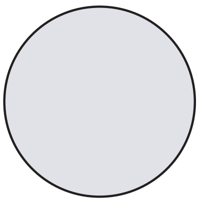
Q1
Have you participated in any course within evidence based design?

- Yes
- No



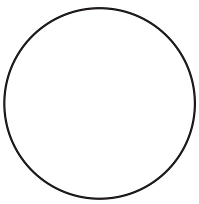
Q2
How would you describe your knowledge of evidence based design in the field of architecture?

- Expert
- Experienced
- Intermediate
- Beginner
- No knowledge



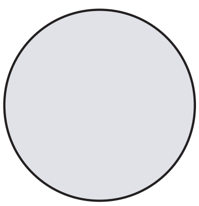
Q3
Have you participated in any course in Grasshop-per?

- Yes
- No



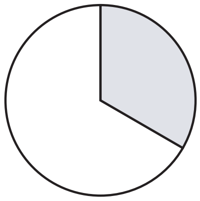
Q4
How would you describe your experience with making definitions in Grasshopper?

- Expert
- Experienced
- Intermediate
- Beginner
- No knowledge



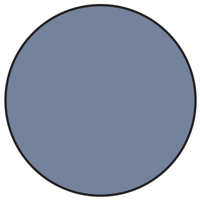
Q5
Have you participated in any course in modelling in Rhino?

- Yes
- No



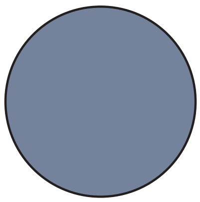
Q6
How would you describe your experience with modelling in Rhino?

- Expert
- Experienced
- Intermediate
- Beginner
- No knowledge



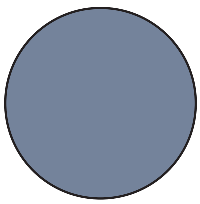
Q7
How would you describe altering the definition to fit the demands of the building program?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



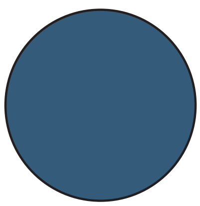
Q8
How would you describe sketching in 2D with modules on top of the sketch drawing?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



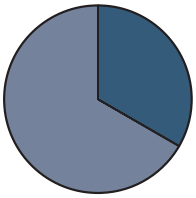
Q9
How would you describe loading geometry back into the definition?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



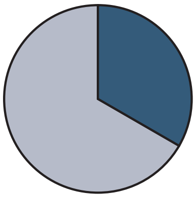
Q10
How would you describe using a fixed selection of modules for design?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



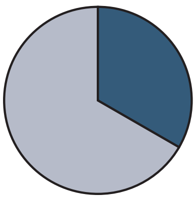
Q11
How would you describe reading the feedback information based on your experience with the prototype?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



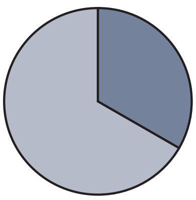
Q12
How would you describe the connection between computer and sketching in hand?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



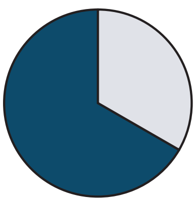
Q13
How would you describe your benifit from using the prototype?

- Very extensive
- Extensive
- Average
- Limited
- Very limited
- Know knothing



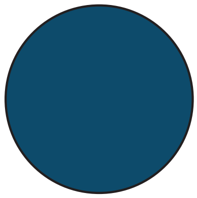
Q14
How would you describe your confidence in the informations and guidance from the prototype regarding your design proposal?

- Very extensive
- Extensive
- Average
- Limited
- Very limited
- Know knothing



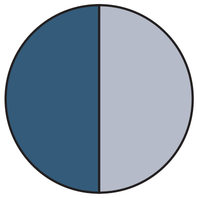
Q15
Have you learned something from the use of the prototype?

- Yes
- No



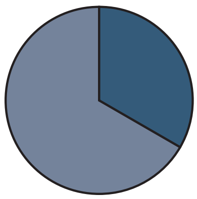
Q16
Do you feel that the prototype support you in your design work?

- Yes
- No



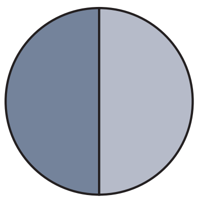
Q19
How would you descirbe altering the definition during the design task?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



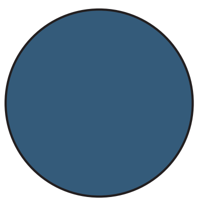
Q20
How would you describe picking objects in the definition and organising the bedroom?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



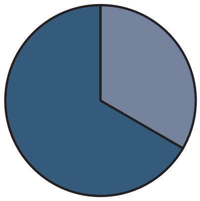
Q21
How would you describe changing between geometry in Rhino and geometry in the Grasshopper definition?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



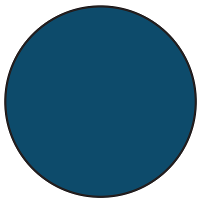
Q22
How would you describe using a fixed selection of modules for design?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



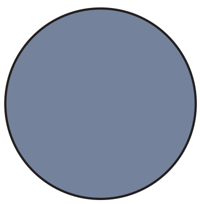
Q23
How would you describe reading the feedback information based on your experience with the prototype?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



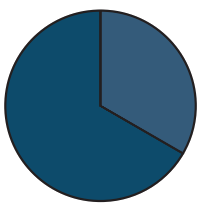
Q24
Do you feel that the prototype support you in your design work?

- Yes
- No



Q25
How would you describe choosing evedence based focus areas from the prototype?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard



Q27
How would you describe documenting the design process through the use of the prototype?

- Very easy
- Easy
- Somewhat easy
- Somewhat hard
- Hard
- Very hard

6.3 Improving the prototypes

From the comments in the questionnaire and the overall interpretations from watching the users operate with the prototypes a list of useful alterations have been contemplated in making the prototypes more comprehensible for future presentation and testing.

Plan prototypes

A more comprehensive object library of wards and bedrooms are needed for the plan prototype.

An automation of the choice of connection points would increase the efficiency of the prototype. Experiments with scripting of possible calculations of area and room intersections and combinations have been carried out but so far the previous method of selecting the points have proven to be more reliable.

Bedroom

From the feedback discussion it was found that the Gross/Net factor in the prototype of 2,1 recently has been changed by the government, resulting in fewer square meters per bedroom than what is considered evident [Møller, C.F, 2008 & Den gode sengestue, 2003]. The bedroom prototype is thus enforced with a Scale module and a Function module where the present Gross/Net factor of 2,0 is typed in using the slider module. The resulting free space areas of the bedroom objects are accordingly offset, matching the new Gross/Net factor. This function is also usable if the building developer demands that the EBD concept is changed throughout the design process. This will jeopardise the evidence foundation of the specific design task because the EBD parameters are overruled.

Light, nature and sound are EBD topics where much evidence proves that patient healing and safety is directly related. Functions that can calculate the sound level db(A) and reverberation would tribute to the assessment of the bedroom. The direct view to nature or other is easily added to the VB.Net module of EBD parameters.

Adding more detail to the object representations enhances the visual impact of the bedroom model. Material and shader components are added to the definition.

Summary

On behalf of the integration of EBD information in the architectural design phase the two main prototype tool functionalities where explored and evaluated:

EBD information usage

The bedroom prototype is very useful for new architects that do not know details about health care architecture, since they are thought the standards through the use of the prototype. This enhances the communication with the other and more experienced architects at the company. It also ensures a standardised platform for stakeholders of the building process to communicate on.

The prototypes, being exemplifications of tool functions, indicate that a full product will require much maintenance in order to be updated. This is an important factor if the tool in future is to be used across the phases of the building process and enforced by building developers, architects and health care counsellors.

Support in design tasks

The survey indicates that both students and architects would find a evidence-based application a usefull and relevant support in design processes in health care projects.

The survey further indicates that the prototypes were qualified for exemplification of functions and operations related to parts of their work practice.

Further development of the prototypes for later user reviews should be on the interface and the exchange between Rhino and Grasshopper viewport.

Although providing what in this thesis is considered an intuitive interface, Grasshopper was source of some frustration among the reviewers. The importance of experience with similar application and the work traditions of the architectural practice are important when choosing a software platform furthering the tool. The level of support that the tool can provide the architects in the given design task is to be weighed according to the cost/benefit rate of educational needs to be able to use the application. Many of the calculations and analysis provided by the plan prototype are embedded in the experienced architects cognitive analysis of the design proposal. The level of experience and level of support differ from user to user and the application should possess flexibility to meet various levels of needs.

All users needed extended support during the user review due to lacking in familiarity with the Rhino environment and Grasshopper user interface.

Triangulation of survey results:

The effect from using combined statements from the two surveys during this project is a method to enhance the validity and reliability of the evaluation of the prototypes. The benefit is in this thesis considered of questionable character due to the reduced amount of repeating respondents.

The following are a comparison of statements from survey 01, Scenarios and survey02, prototypes. The statements reflect the change in some of the respondents perception of the EBD tool. It is also used to evaluate if the prototypes meet the initial goals set before programming.

Q2, Survey01 –Survey02, feedback statement & Q3, Survey01 - Survey02, feedback statement

The results indicate that where the architect before the prototype survey, showed much reluctance in the applied effect of the tools, the prototypes have proven that especially the bedroom prototype is relevant for inexperienced architects and communication of standards among stakeholders of the building process.

Q6, Survey01 - Survey02, Q13

The benefit of the prototype does not resemble the expected use of the EBD tool. The decrease in benefit of the plan prototype show that the integration of sketch and CAD drawing does not function optimal for the architect and that the prototype design have not met the intentions set in the thesis.

Success rate among participants

The success of the tools derived from the statements of the architect is in no way representative of the architectural profession or other design professions with interest in health care design and optimisation. When applied anyway the answer is to be found within the specification of the knowledge level, which represents a narrow discipline, which explains why those results gathered are interesting even though the level of reliability is weak. This fact is to be further discussed.

Trade off between validity and reality

In order to gain primary empirical material the survey has taken the possibility of triangulating quantitative and qualitative methods. A survey was conducted in order to understand the preferences of professional staff at Friis & Moltke. This has provided a great opportunity of applying the tool to the complex reality of the respondents.

First a survey was produced and organized accordingly

Second a test pilot survey was conducted with students of A&D in order to calibrate the procedure and gain the highest validity possible

Third, the first survey was conducted with 3 respondents at Friis & Moltke.

Fourth, the second survey was conducted with 1 architect at Friis & Moltke.

It should be noted however that the amount of respondents are not significantly valid for a broader generalization of the research tool. It does however apply a reasonable product, though one should keep the insecurities in mind.

EPILOGUE

7.1 Conclusion

The conclusion of the thesis encompass the results throughout the project process with reference to the academic goals and project goals [Methodology, pXX]

Academic goals

One of the goals of the thesis was to analyse architectural health care design practice and methods for applying evidence based knowledge in the design process. This was achieved by conducting interviews and case study of Medicinerhuset and the architectural company Friis & Moltke, Aalborg. From the interviews it was found that development of a software based EBD tool for architects was essential for optimising the work flow in EBD concepts. In order for EBD concepts to have effect in health care architecture it was found that the access to information and criteria assessment in the tool was important. Derived from the analysis the tool functionalities were:

+ Providing, storing and documenting EBD related information and data

+ Increasing communication between stakeholders

+ Evaluate and control EBD concepts and criteria in the design process.

To challenge these criteria the design focus was founded on the software platform of Grasshopper, an associative modelling tool capable of providing the architect with real time feedback from parametric design iterations. The purpose of relational design feedback was found to:

+ Support the architect and stakeholders through the design iterations

+ Question the design proposal in areas otherwise neglected

+ Improve health care design regarding patient safety factors

From exploring EBD concepts the context frame in designing the prototypes was chosen to be patient safety and guidelines for improving the environment near the patient. This was explored from a parametric focus on floor plan development and patient bedroom design. Through these topics the impact on patient safety was defined in physical measures and spatial relations constituting the parameters of the prototypes. The prototypes development was conducted as exemplifications of EBD functions and methods in architectural practice to

+ Evaluate the tools impact in the architects design process

+ Assess the usability of the specific prototype functions for further development purposes.

To evaluate and conclude upon the design requirements of the prototypes survey and scenario methods were used. Based on feedback and the data from seven questionnaires from architects and architectural students, the prototype design specifications were:

+ Prototype user – the architect. The architect was found to have the most important role in the evidence based design process.

+ EBD context – patient safety. This focus was considered well documented regarding evident knowledge and guidelines and more applicable for the design of the prototypes in terms of geometrical representation and calculation.

+ Technology platform – CAD modelling. Using and exchanging CAD models and drawings were found to best fit the architect practice and work flow.

+ Design tasks – sketch and detail in the early design phase. It was found important to ensure that the EBD concepts were entailed from the beginning of the design process.

The prototypes were designed as parametric definitions in Grasshopper. The goal of creating scripted prototypes that could be used to evaluate design parameters in 2D and 3D modelling was fulfilled. The method of expert review was used as part of a survey to evaluate and reflect upon the prototypes functionality and impact within architectural design practice. Five respondents participated in the survey; only one respondent was a graduate architect with considerate experience in health care design. The goal of creating valid and reliable data and statements to support the prototype evaluation was barely met due to low number of respondents and answered questionnaires.

The survey proved that the prototypes fulfilled the expectations but needed more detailing and more focus on the relations between EBD criteria to be used in architectural practice. Further more the architect stated that the practice would be able to save time and effort searching for knowledge and advise when provided with the EBD tool.

Project goals

The prototypes were designed around a set of basic functions and two main case prototypes. The functions were Reference module and Assessment module; the main case prototypes were Plan prototype and Bedroom prototype.

Both basic functions were designed with the purpose of integrating evidence based design information and design criteria in the overall prototype design process.

Following are the concluded benefits and inconviniences of the prototypes conducted in this thesis

Benefit

+ Linking calculations and sketching in CAD modelling

+ Documentation of the assessmed EBD impact for building developer

+ Information and references supporting architects inexperienced with health care architecture

+ Standardised communication among stakeholders

+ Accreditation score and control of EBD criteria

Inconveniences

+ Rigidness of sketching in CAD software

+ Functions are to basic for experienced users

+ Software platform unknown to users

+ Interface to confusing

Both basic functional modules were found successful in providing the user with important design support and related information as well as alert notes when evidence based design concepts had been violated. The assessment modules criteria score was found useful to the architects. In general the translation of evidence-based knowledge was in found reliable.

From the user review the design functionality of the plan prototype is found less relevant than the calculation functions. The benefit of the calculation function was the ability to link between the analogue task of calculating specific building values and drawing with CAD modelling.

The bedroom prototype was found successful in providing a design frame for the optimal patient bedroom with regard to evidence based design and patient safety.

Both prototypes were found to be exemplifications that fulfilled the conceptual functions of a usable tool used for analysis, control and evaluation of evidence based design criteria.

From the surveys it was found that users with extensive experience in EBD found the prototypes less usable. The consequence of this statement indicates that the relevance of the tool in design practice is depending on the individual users prerequisites and need for support. To better suite the tool alternate user gateways and functional profiles must be designed so that experienced user do not consider the tool functions tedious and trivial.

The prototypes were considered a benefit for inexperienced EBD users that has the possibility to obtain information and learn about EBD concepts from the tools. Using the tools on a regular basis would strengthen the communication between stakeholders and colleagues in the building process as a result of the prototypes EBD standards.

From a building developers perspective the tools are found attractive as the accreditation list in the bedroom prototype is valuable documentation of the design process and the EBD criteria of the project but within the context of the prototypes the level of detail is found to low to be applicable for use.

Considering the goals of the thesis the design explorations have created foundation of an extensive understanding of the complexity of integrating EBD concepts in architecture and to assess the expected impact they will have on health care buildings. The offset of using parametric design to be able to create informed design decisions have proven to be the infancy of a larger assignment to be solved in the future. This thesis have proven that it is possible to affect the architectural design process with control and assessment without robbing the architects their design possibilities.

Grasshopper as tool platform

As a platform for programming prototypes Grasshopper is found fully functional for the user with intermediate experience with 3D modelling.

For the inexperienced user another platform is needed. The platform choice is found best to be compatible with AutoCAD and BIM technologies.

7.2 Discussion

The following is a discussion of the thesis process, contents and results with the authors own subjective statements embedded to emphasize subjects of importance regarding the discussion of a future EBD tool.

Problem

"How to design a digital parametric tool for evaluation of evidence based knowledge- and design parameters in architectural health care projects?"

One of the main challenges of this thesis has been the translation of evidence-based concepts into measurable parametric definitions and to assess whether or not they would be beneficial and relevant for the architect in the design process.

During the exploration of the topics it became clear early in the process that trying to encompass all EBD topic and value them accordingly would be to big an assignment for a thesis.

Learned from the scenarios and the surveys is that the experience and best practice of the architect in many design tasks exceeds the level on which the measurable EBD criteria operate. Derived from the expert review at Friis & Moltke the architect is capable of reading, interpreting and deciding upon a plan drawing with pervasive knowledge and speed. The manual operations within the prototype prolong these design tasks making the apparent use of the tools seem tedious and trivial. But the purpose of the tools is the tacit design knowledge and evidence based criteria. It is the many layers of information rules that are hidden from the designer's perception that justify the use of the tools. The parametric logic of the application is not biased by deadlines, creative visions and preferences regarding specific design solutions. This further more strengthens the tool usability.

That being said another topic worth discussing is the level of freedom within the design process versus the real time computational control executed by the tool. The fact that the tool is designed to both inform but also limit the designer by assessing the level of criteria fulfilment has posed a difficult subject to deal with during the project. This thesis has a focus on patient safety as EBD parameter. During the process of designing the prototypes the many criteria and geometric boundaries within the definition seemed to limit the design more that benefit from it asking the question; is a hospital of optimal safety a good hospital? The application is not able to consider the fact that standardised and uniform organisation of space although safe for the patient in every way might worsen the situation because of the lack of value, perception and aesthetic sense in the designed script of the tool.

In order to create a successful product in the future the EBD tool must seek to combine the best practice from the architect with the addition of information and knowledge of the tool. Designing facilities for health care is a continuous process of priority and compromise. The combination of strengths could be enforced by less tool focus in the actual design part of the process, but use it more as control. The prototype will this way simply put ask all the questions regarding the EBD concepts parallel to the actual design process. The kind of questions that the architect would not have thought of. This depends on the level of confidentiality within the design task, the subjects and the experience of the architect. This would be a time saving procedure since the inexperienced workers would automatically obtain information relevant of the immediate design questions instead of either having to interrupt a more experienced colleague or trying to find the question through extensive time consuming research and analysis.

An issue that had not been encompassed thoroughly during the design of the prototypes were the issues regarding individual work preferences. Users that are used to work with applications and computers would properly accept assigning parts of the design process to the computer more than architects that prefer the more traditional analogue methods of sketching and designing using pencil, paper and ruler.

As a knowledge based tool the application have the potential of unifying stakeholder across the different parts of the building process by offering standard descriptions of EBD concepts and criteria, sharing knowledge and documentation of the design process.

But the main issue with the development of the EBD tool is that it is not yet able to perform smart evaluations upon design proposals. The application has to be fed all information and updating it will require a great amount of maintenance. The prototypes are designed to rely on measurable geometrical statements and conditions. Examples of letting the architect choose parameters from a checklist are a method of encompassing non-logistical founded parameters in the EBD tool. Embedding areas of evidence that rely on perception, sensing and experience-based relations pose one of the next great assignments in the development phase.

"How is a parametric application tool designed in Grasshopper, to support evidence-based design concepts in healthcare building projects?

"How are the application prototypes integrated in the design processes of an architectural practice?"

Good health care and patient satisfaction is proven not to be directly related by physical space. The investigations at Medicinerhuset found the bedroom areas smaller than the recommendations. The accreditaion reveil a high level of satisfaction thus proving that other factors have impact on the perception of treatment. This means that the aesthethics and the sensing are perhaps more relvant to study and encompass in the tool development in order to improve the recovery and healing of the patient.

APPENDIX

8.1 Tools, models and methods in the building process

The quality- and output- effects of hospitals are measured and assessed by different systems. This is done to guarantee both performance and quality of the built facilities. The following section is a layout of some of the key methods used in the development of hospitals, dealing with building process management and evidence-based design.

Evidence-based design: Assessment and accreditation models of healthcare buildings

The list of healthcare and hospital accreditations consist of an international accreditation system and a paradigm, some non-negotiable, quantifiable and some metric, others more fluid and quantitative, survey based. They are mostly based on self-assessment and external peer process to improve the value of healthcare operations and constructions. The common rule of the accreditation systems is that they are evidence-based. The effect of accreditation systems is of market value and international medical tourism. [Wikipedia.com, 2010]

EDAC

The Evidence-based Design Accreditation and Certification program is for individual partners in the building process around healthcare building projects. It is a program that educates developers, architects, designers and constructors in the correct interpretation and implementation of evidence-based design knowledge. The accreditation certificate is received upon graduation and passing of the final exam of the program. [healthdesign.org, 2010]

GGHC

The Green Guide for Health-Care buildings (GGHC) originates from Roger Ulrich's and his original 28 specific environmental features promoting better health-care. [GGHC/H2E, 2007] This has been extended to encompass building, operation and performance criteria to which a health-care facility will be evaluated. The GGHC is a quantifiable sustainable design toolkit integrating environmental and health principles and practices in the different phases of a buildings lifecycle. The accreditation system consists of a metric checklist with a total sum of 72 points in categories of construction credits and operations. A high score in the GGHC is a mark of good medica l standard, treatment and healthcare.[GGHC, 2004]

DDKM

Den Danske Kvalitets Model for sygehuse The Danish Model for Hospitals (DDKM) is an assessment model developed by the Danish Institute of Quality and Accreditation in healthcare. It is approved by ISQua, the international society for Quality in health-care. It consist of 104 accreditations standards and the process is divided into four phases of evaluation and assessment, the first being basic evaluation, secondly a self-evaluation, thirdly intern surveys and lastly extern surveys. It is a relatively new model, developed in 2009 and the goal is to reach accreditation of all Danish hospitals by the end of 2012. Region North Jutland is to be accredited from September to December 2010.

The model is a national and cross-disciplinary system of quality that is to give the Danish population higher value and better patient treatment in hospital service. [Ikas.dk, 2010]

Architecture: Information control in the building process

All the information in the design process has to be structured in order to ensure that all parties of the design process are working towards the same objectives. How is all the different information structured, what are the present tools and what are the future tendencies. This is investigated with the perspective of designing information applications

Lean Construction

The building industry has used the Lean Construction (LC) system after its invention in the 1970's (or in 1970) as part of a production planning process. The LEAN construction system works as a project-based production process, where subjects as waste, material use, time planning and communication between developer, consultant, architect and constructor is in focus, attending the benefits of the master builder concept. Opposed to BIM which is founded on technology and communication, LC is a method to structure the conversations across parties, to design the logistics and network connections in the design phase. BIM and LC concepts are both essential to the optimised building process. [Wikipedia.com, 2010]

Environmental planning

Developers might demand of their consultants that the building proposal proves to live up to the Danish standards of environmental planning. This covers the impacts and effects, different phases of the building project will have on the nearby environment but also the quality and production of the materials used in the construction and assembly of the building along with the service of the finished building project. Topics such as form, location, function, technical installation and construction all have an impact on health and the environment.

There are different methods to guarantee that the building lives up to these standards. One is the web application ABC-planner [abcplanner.dk, 2010] another is the schematic metric application BEAT2002 developed by NIRAZ and SBI [Sbi.dk, 2010] Both represent lists of goals, risks and means and end up with a graphical representation of how well the goals have been met.

ABC planner

Derived from the interview with Gudrun at Friis & Moltke the system tool ABC-Planner was discussed. The tool is a licensed web application. The main theme of the tool is environmental planning and it is used by architect and building developers when working with environmental planning in building projects.

The application requires subscription and payment in order to have access to the database and the matrices behind ABC-planner.

The tool provides environmental planning knowledge in the form of suggestions and literature links in a strict schedule in order to give the user a reader-friendly overview of the different goals and means regarding different phases of the building project.

By choice and the entering of values in the matrix you have the possibility to use ABC planner as a user as documentation of your choices later in the planning process or as a logbook of the project.

Furthering the planning process, the methods and goals of the ABC-planner gets more detailed ending with an Environmental Map, the schematic documentation of the results from the previous planning processes; Mapping of environmental influence, prioritisation of influences, defining environmental goals and incorporation of environmental means.

Pros

+ Provides a structural overview of elements and guidelines in order to fulfil the environmental planning

+ Good and simple interface

+ Possibility to write additional options and user specific content.

Cons

+ It is dependent of the given standards and requirements of the local municipality in charge.

+ Requires knowledge on environmental planning

+ Gives no real values or analysis of the quality of the parameters chosen

+ Is dependent on a continuous maintenance in order to keep the knowledge updated

ABC-planner has in the past been used by Friis & Moltke, but since the development of the application has halted the last couple of years they are reluctant to use it in the future. But the structure and the dynamic aspect of the tool is something that Gudrun thinks is an essential part of a future tool.
http://www.bygnet.dk/bygnet/go?action=701&id=0&next_page=10278

Examination schemes

Another tool of usage by architects is the examination schemes (Gransknings-skemaer) specifically developed according to the project at hand.

The Århus architects used these to clarify whether or not they have met the goals of given topics or phases in the design.

The schemes are written by the architect or the developer. They consist of questions related to the building process and are marked with a yes or no depending on the state of the subject; whether it is solved or not. The results are then discussed and the appropriate actions are taken

Pros

+ The schemes give a written overview of the criteria and goals of the design tasks.

+ The schemes can be rewritten and later examined in case clarification of some of the goals are needed later in the process

+ It gives the reader a straight answer to each question formulated in the process

Cons

+ It is primarily a self-evaluation tool and therefore the effort in filling out the schemes with relevant and thorough questions rely on the individual company

+ It is document based

+ Relations between topics and questions are visually and perceptively difficult to comprehend.

LUDOC

LUDOC is an IT documentation tool developed as a way to maintain the accumulated work experience between stakeholders and projects. It is compatible with bips and the B1.000 database. This database holds references to libraries of building objects and metadata. The interface is a lot like Microsoft word and therefore documentation of the building details are easily fitted to the individual users needs.

LUDOC offers many possibilities for tracking information related to the construction phase. It saves the counsellors, architects and constructers from starting from scratch every time a new project has to be planned in construction detail.
http://www.byggecentrum.dk/data-og-software/ludoc/

Software tool: Building information modelling

BIM structure and management

The Digital Construction, TDC, is a digital communication and documentation method based on Building Information Modelling, BIM. It is a platform designed for cooperation, communication and technological utilities, by a large network of organisations with the goals of improving the building processes and future developments of digital media and IT solutions in building industry.

A common misunderstanding is that BIM is all about the geometrical representation of the CAD model developed through the method. It is true that the product of DDB is a 3D model but the core essence is that of building management and the storage of information within the digital model and network specifically created around it. Each project is unique.

A building process under the direction of DDB consists of four phases under which the digital building model is developed. These are the Development plan, the project proposal, pre-project and main-project. To match these different project phases and their different needs regarding input, feedback, communication and documentation, different layers of information are defined, through, which the progression of the project is made clear, interpretable and executable to the parties involved. There are 7 layers through the lifecycle of the project.

+ “Needs model” (Developers program, demands, constraints, terrain and building site.

+ Visualisation of proposal (volumetric and spatial models)

+ Decision-model (functional properties and the physical building solution)

+ Authority and regulatory project

+ Bidding project (foundation for bidding, calculation and production planning)

+ Construction project (foundation for production and construction by the contractors)

+ "As built" model (documentation for the entrepreneur)

It is up to the developer to concretise what his consultants must provide of digital data and information regarding the information layers needed in the project and process.

The BIM model is built up as part of the information layers and consists of objects and object classes. These can be defined in various CAD software such as Revit, Tekla or ArchiCAD. They have to be defined as Industry Foundation Classes (IFC), which is a classification standard of how every information embedded in the object in the project is to be electronically represented.

The objects, defined as IFC, can consist of different information typologies. There is the physical objects information such as the geometrical definition of points and vertices of e.g. a wall object or a door object. This can also be the complementary set of more than one object, e.g. the space encompassed by 4 wall objects. Secondly there is the information regarding property, attribute or capacity, which is a type of information that can be assigned as a non-geometrical parameter to the object.

This category combined all the information that does not lie implicit in the geometry, e.g. the Thermal value of a window or the fire resistance of a door. The properties are per definition a parameter in the IFC classification. The property category implies the information layer of the BIM process, which is determined on the progress of the project.

Confusion also occurs when referencing to BIM as being partly object-based and object-oriented. There is a distinct difference. Whereas the object-based concept is founded on physical representation and geometry in 2D/3D CAD systems, the object-oriented concept is an understanding of the object as defined by form, property (performance) and relations to other objects.

The object-oriented concept includes 3 object definitions to which an object belongs

Spatial objects

Physical objects

Compound objects or conceptual units

The last category is where the true power of future developments of BIM lies as the technology development will push the understanding and use of BIM, buildings and objects towards more abstract levels like philosophy or mathematics. By using BIM as a mere physical modelling tool the capacities of simulations, performance and relations in the programming technology is not fully utilised.

A present feature of BIM in constant development is the simulation ability. Simulation has always been a part of the building process, from the artistic perspective sketch, plan and section drawn by hand, the later low-tech computerisation of 2D CAD drawings to the development of the multi facetted three dimensional virtual simulation of the building model.

In BIM simulations are run upon the 3D model to view consequences of design solutions. This is done in order to establish a controlled reality where studies of various system behaviours under specific conditions might help in making informed design decisions.

These simulations cover various topics such as:

+ Visual 3D-simulations used as a cooperative tool in the early stages of the building process. This is used for collision control, user involvement, and as a communication tool.

+ Thermal simulation, colour codes representing heat loss

+ Acoustic simulation

+ Indoor climate, heat/cold, radiation, ventilation simulations

+ Fire simulation

+ Light simulation

+ Stress and strength simulations

+ Building site simulation for planning and logistic control

+ Cost and operating economy simulations

As part of the layering of information it is again up to the developer to put up the demand regarding run simulations. Doing so, the key considerations of the simulations standards are the need of data and the validity output provided by the simulations to determine whether or not the simulation is reasonable, realisable and cost-effective.

Simulations are either project specific or licences from software vendors, and therefore they might pose an economic factor worth considering. Simulations might also have to be programmed to meet the specific needs of the developer, and thus the hourly cost of programming also becomes an issue.

Autodesk Revit

Autodesks extensive family of products offer a strong alternative to using Rhino and Grasshopper.

Their newest version of Autodesk Revit Architechture presents a new GUI, a geometric modelling application with associative and parametric relations.

The software lets you control your digital building project so that it lives up to the BIM promise, determined by the Danish government for future buildings.

Revit is specialised in keeping together all of the building information, making it easy to use and design, and therefore no programming and scripting skills are needed.

That being said Autodesk has also extended their Design Center feature which is an online user database with downloadable analysis applications and plug-ins created by Autodesks developer partners. Therefore Revit 2010 has improved the API (application programming interface) making scripting and programming of plug-ins easier, still requiring experience in .NET programming language. (Visual Basic . NET)

Revit's strength lies in the analysis functions of the package. It is primarily used for analysis of energy consumption, sewer drainage and construction costs.

As of now the main goal would be to script analysis and simulation applications for use in Revit. I don't understand this sentence.

Usage of the family libraries of objects in Revit is improved with the accessibility of the API.

Together with Revit the NavisWorks extension pack ensures interoperability between most parties of the building process.

http://www.cadalyst.com/collaboration/building-information-modeling/revit-architecture-2010-cadalyst-labs-review-12820?page_id=5

Software tools; Design exploration concepts

Operating within the field of architecture and digital design technologies the following section is a layout of previous and contemporary tendencies in architecture.

The use of computational power – different discourse of digital design in architecture

Architectural theories and concepts have been developed or have had a renaissance since the introduction of the computational powers of the algorithms. Many of the concepts share relations between computation and parameters but differ in purpose and perspective.

Recent development has divided the profession in architects and designers in the much-discussed terms of form making and form-finding.

Form-making

Form-making is an advancement in the skills of creating form by user-driven geometrical modulation of 3D objects, surfaces, splines, NURB-curves and vertices in representation and visualisation whereas form-finding is the concept of finding the form through iterative optimization of the behavioural links between the parameters and performance of the individual coherent parts of the 3D-geometry. Formfinding dedicates the somewhat more engineering perspective where different rationales are calculated and the form responds to the outcome so that the preferred performance is improved.

Form-finding

Form finding is a procedure inspired from the manufacturing process of other professions e.g. the automobile industry. Here the software drives the performance analysis of a windshield under influences of wind forces. The simulation and analysis of the forces indicates where criteria are less well met and where optimisation might occur, in form. It is a process of combining a geometrical and later physical object with information and then evaluate the performance of the object in various setting and environments to create evidence and informed design decisions.

Generative architecture

Computers have opened up the possibilities to test and elaborate on spatial and genetic concepts applied to space and form.

By use of generic algorithms the software is informed of the rules of organisation of space that can produce unlimited amounts of design variations. These concepts pertain to the concept of Generative Architecture. Here the rule of the algorithm is in focus. The organisation of space could be ruled by a mathematical expression like the Fibonacci numbers or context specific parameters.

Performative architecture

Another concept that is being put much effort into is that of Performative Architecture. It is used to meet for instance the concept of sustainability and environment. A building can be evaluated upon its performative character this be the way it performs in matters of energy consumption or natural forces. It can be external forces of the environment or it can be the internal performance of the functions.

Derived from this concept are also ideas of behavioural architecture and responsive architecture. These concepts rely on an interaction concept between parts of a building, the building, the user and the environment. This might be façade aperture related to solar power or light sensoring according to presence of users within a distance of the building.

Algorithmic architecture

On a more mathematical and computer programming level the concept of Algorithmic architecture is apparent. The constructions of procedural scripts and iterative pieces of code ruling the overall calculation application performs generations of looping computation in order to seek factual knowledge or an optimisation continuum within a task.

Parametric architecture

The link to parametric architecture is not far. The usage of computer programming skills is merged with the design skills in the process of analysing problems and sew the algorithmic solutions in order to experiment, test and try out performance abilities, spatial relations or whatever the task may be.

Where there once was a specific distance between computer programmers and a designer, the designer now becomes the programmer with the ability to create his own applications that will perform the task, crush the numbers or evaluate the circumstances needed in order to make informed choices.

By use of associative modelling and a focus on the parameters, drivers and constraint within the model the designer is able to change the definitions, the expressions and values of individual components defining the geometrical relations and the geometry, and performance feedback is then instantly used to optimise the model and the information contained within it. This approach will be adapted to the concept of Evidence-based design processes in the hospital architecture in order to write the optimal code controlling the right parameters, creating the right relations thus receiving the appropriate output needed in order to fulfil the decision foundation and criteria of the task at hand.

8.2 "Day in the life"- Scenario

Analysis of present sketching process and software practice

Scenario conducted at Friis&Moltke with two architects with a focuves on the analogue and digital processes in designing for a project for a new hospital in Thisted.

The purpose of the scenario is to identify present work processes in healthcare design using software applications and sketching methods.

One architect was given the task of performing alterations in an existing CAD model in order to observe the tasks and effects.

Another architect was given the task of showing the sketching process of a project.

Digital work process

The architect was to change the thickness of walls and size of doors in a floor plan of a hospital room in an existing 2D CAD model of present healthcare project. Following is the actions and events from the task:

The architect searches for the project folder. This is located on a server. All projects are organised by name id in a folder hierarchy. The name prefix consists of a code of letters and numbers. Execution of the file opens the CAD software, AutoCAD 2008. All drawing information is layered. Layer of change is located. The wall geometry is selected. Wall geometries are (instant – I don't understand) instance blocks of an object.

New specification is either typed in the command line of AutoCAD or the object geometry is altered by pulling with the selection tool to an adjacent snap point. Difference between local and global changes. Local changes can be made to the individual block, changing its geometrical attributes. Global change will change all blocks in the family associatively.

Selecting the door object and changing the size automatically changes the wall panel size because of associative dependence between object-families. This is applicable for a selected group of objects, designed by the software developers. Layers, vector lines, text, hatch and colour represent drawings. Printing is done by exporting to pdf format. In Acrobat Reader all layers of the drawing are visible and can be turned on and off prior to print on paper.

Other observations

AutoCAd is used both for construction drawings and for sketches, called "Dummy sketches" which is graphical mock-ups. All sketches are based on a modular grid for construction and calculation purposes. 3D modelling is done in the 3D modeller embedded in AutoCAD and Rhinoceros 3D. 3D modelling is done for presentation only. Not for BIM. Other software applications are used rendering. 3D Studio Max is the preferred modelling application, with Vray 4.0 renderer for rendering photorealistic and artistic visualisations. Exported lines are used in illustrator to create vector graphics used to present sections and plan drawings. Photoshop is used to create imagery based on layers and pixel graphics.

Visualisation work is outsourced to third party contractors. These are chosen by the architectural firm. BIM technology is used on an exploratory level by one of the workers at the company using AutoDesk Revit. BIM is not integrated in the work routines and in projects yet.

Future needs from software applications

The architect would like:

+ to have the possibility to extend the library of options in autocad.

+ an easier file prefix method.

+ to have Revit more integrated with the many information and data layers available.

+ to have more freedom for experimentation with software applications as part of the work.

Sketching processes

The architect was asked to elaborate of the sketching phase and the progression in the design proposal.

The sketching phase was mainly done by hand with drawing on opaque paper using pencils, brushes and marker brushes. The amount of space and the calculations upon the number of rooms were done using a calculator. Drawings were done upon a modular grid. Drawings were presented to other architects and evaluated based upon the building program and experience of the individual architect. When a drawing was detailed and ready for further process it was handed to another architect that would then make the CAD drawing based on the hand drawing. Design changes were made on opaque paper upon updated CAD drawings that were printed out on paper. The cataloguing and documentation of drawings were up to the individual architect after the task had been completed.

8.3 Prototype scenarios

RAD1_A model

Definition
The tool itself is a basic modelling application. The designer enters project specific data into the application and receives diverse output from which his design is guided.

The tool requires no previous developed CAD models, little experience in CAD modelling, limited knowledge in healthcare projects but a basic idea of the concept of the project.

It is the purpose that the designer can begin to layout ideas and concepts of form and function in a geometrical ruled and evaluated way while receiving immediate feedback and references to results and extensive knowledge.

In addition to the conceptual design of the floor plan other issues and evaluation parameters will be introduced to the designer to create a more informed design plan.

The tool is used in the idea/program phase and the sketching phase of a project.

Development
The tool consist of parametrical entry paths where the designer can feed the application with constituent data, defining the project characteristics, the desired functions, goals and limitations. This data is used to determine the style of the application, which parameters to be available and which references in the knowledge database to draw upon. The data is entered in the slider parameter module. This is designed with a field for output data. An expression is defined in this module calculating the output.

Based on the value of the output the 4 point surface module or the Box module is initiated to create an object which size is characterised by the output data as either area in m2 or area plus height (3D).

The function Instance module is linked from which the designer copies and replaces the geometry in the Rhino document. Feedback to the Grasshopper definition calculates the present number of instances and is subtracted from the initial number to indicate how many rooms still need to be replaced.

Feedback
The application presents a document style setup in the Grasshopper environment with calculation fields and building blocks available for the designer to begin his initial sketching.

A set of style specific building blocks, as either 2D surfaces or 3D building blocks, are defined and can be applied to form the building plan. The designer has visual feedback at all times together with updating calculative information.

When limiting the specified criteria typed in by the designer, the application parameters change background or surface colour to red highlighting the parameter in error. The visual feedback is accompanied by a calculative hint as to see the state of the error along with a link to more material on which to get further information in a database.

The designer may at all times decide to overrule individual erroneous parameters by simply checking them off, giving the designer the choice of either following the rules of the application or deciding by himself.

Issues

The database references need to be in a spreadsheet that Grasshopper can call upon in order to reveal the data. This is done in regards to certain topic specific Boolean values and operations.

Checking parameters on and off might pose an issue if writing inside a VB script. This has to be done like the preview mode in Grasshopper.

Further development

As the designer's plan takes form, each of the rooms can be specified use and characteristics that can be basis for further evidence-based design evaluations.

Exemplification

A floor plan calculation

Development

The total area of the floor plan is entered, the number of beds is entered and the result of the area of every bedroom is given as feedback. The value is connected to a square surface defined as a 4 point surface. Instances of this surface can then be copied and multiplied and rearranged to support the designer's idea of the overall layout.

Feedback

The feedback is given by values representing calculations of the data entries. The size of the bedrooms is defined by the surface. The arrangement of the rooms to create a floor plan. When too many rooms have been copied the value turns red.

RAD1_B model

Definition

The tool is designed to match a specific topic in healthcare. It is primarily an evaluation tool to support or test specific elements that the designer is not capable of judging by himself.

The tool is fed with a part of a CAD model already made within a CAD program. The model represents the designer's ideas of a parted solution merging his architectural vision with functional goals and requirements.

The designer chooses from a specific list in which areas the plan is to be evaluated.

The purpose of the application is to test and rate specific parts of the design layout prior to further development. The tools feedback is part of the critical decision process.

The tool is used in the sketching and in the early part of the detailing phase of a project.

Development

The application is fed with geometry. A definition document is designed to match a specific topic of healthcare architecture. The designer chooses the topic and runs the specific definition before loading the geometry. The 2D or 3D model is then imported into Rhino and linked in the geometry parameter in Grasshopper. The geometry is here divided into polylines and surfaces. Additional surfaces between vertices are created but not displayed by toggling the preview function of the modules. The geometrical specific data is recalculated into values that are used by the tool to evaluate the certain evidence based and ruled scripts.

Each script runs a number of action codes and returns a value or output that is the Boolean value of assessment.

The designer links the script components one by one to begin the evaluations.

Feedback

The feedback is the geometrical model. This is known to the designer beforehand since it has been made in another CAD application.

Based on the recreation of the geometry the Grasshopper defined model is represented, hiding the original geometry. This way Grasshopper can provide a colour specific feedback without the disturbance of the else underlying geometry.

Basic values of areas and number of elements are returned and displayed.

The evaluation scripts are present in the Grasshopper definition for the designer to chose and link his model from.

Based on the assessment the designer can print the erroneous parts and remodel his model parts in the original CAD software.

The designer can toggle references to literature, results and evident guidelines as he/she pleases during the evaluation. When bad evaluation occurs, a reference list with literature pops up or is highlighted.

Issues

Geometrical errors in the compilation of the vertices and surfaces pose a problem. Depending on the CAD software used to create the part of the model the functionality of the Grasshopper scripts might be prone to compatibility issues.

Attaching and detaching links might demand a reset of each script or the definition in order to maintain a constituent data structure.

The complexity of the model might require definition of elements in order to have the scripts to understand the geometry and how to run and evaluate it.

Further development

Additional values and entries might be performed to further strengthen the evaluation.

Exemplification

Evaluation of the number of rooms in the floor plan that receives daylight and the approximated impact of each room on the healing period.

Development

A definition that evaluates daylight parameters and healing effect is opened in Grasshopper. The model is loaded in Rhino and linked to the script.

An arrow representing north is oriented so that the direction of the model is correct.

Location and time specific values are entered to calculate the sun path and azimuth at the model location.

2D model

The designer selects the polylines representing the windows in the floor plan.

3D

The designer selects the surfaces representing the windows.

The script now calculates the average amount of daylight over a year in the rooms.

The designer chooses the surface depicting a specific room.

The designer specifies the room functional use and the patient category.

These values all point to specific data in the script that are hidden from view since it is to be used in the calculation.

The designer is given the option to enter various material specific values to further calculate transmission, heat, and glaze.

The script calculates the levels of daylight and compares the value to a specified border value, resulting with a resulting diagram indicating how well the room is susceptible to daylight with impact on the healing process.

Feedback

The amount of daylight in each room is represented by a coloured surface covering the area of the room with a gradient going from blue to red depending on the average amount of light.

The resulting circadian rhythm diagram of the patient specific room is shown which is used as evidence based validation. The diagram is compared with the optimal circadian diagram showing how well the room performs in matters of daylight and healing by light and darkness.

RAD1_C model

Definition

The tool is an extensive application that evaluates and assesses larger plans and models.

The tool requires a detailed 3D CAD model that has been developed as a part of the Digital Construction paradigm.

The purpose of the tool is to create a valued list of specifications that give an overall score showing how well the project is expected to perform when built, based on evidence based research and results.

The result is intended as a tool to help the developer guarantee optimal performance of a building project.

The application is primarily intended the detailing and proposal phase of the design phase as well as the project phase regarding the overall building process.

This product is moreover a collection of many scripts, smaller and larger applications combined into one overall product.

Development

Before loading the complete 3D BIM model into the software the user is presented with a list of possible evaluation categories. This list is checked so that it matches the requirements and intended goals of the building program and various design and technical manuals.

The BIM model is loaded into the software.

When confident that the geometrical interpretation and import have been successful the designer performs each individual evaluation and assessment. The result and score is stored in a hidden spreadsheet that is called upon at the end of the operation.

When all applications have been executed a final list is contemplated and available for reading, interpretation and printing.

Feedback

The feedback is a complete output list with all the evaluations sorted by category with the individual scores within the category.

The overall score serves as an evidence based design and healthcare architectural accreditation value.

The score is subdivided into percentage groups of the performance of the building. Along with the score is a categorical list of "red" bars highlighting the issues to which the project did not meet the minimal requirements. Here the developer and the architect can decide if measures and actions are to be taken.

The limit of percentage to which a building will fail the overall accreditation is set by a panel of experts within healthcare architecture, evidence-based design and hospital practice.

Issues

Because the tool will have a great impact on the assessed quality of the project proposal the expectations of operability and liability within the functions, geometry and scripts are big. Therefore the part with most emphasis is not the modelling but the structuring and connection between information and evaluation. Rhino Grasshopper is not known for handling of large models and data.

Depending on the extent of the evaluation topics great effort in typing, specifying and selecting the right information and metadata is prone to be time consuming and confusing for the user, that be the architect or the developer.

Compatibility between BIM modelling software and Rhino is at this date not extensive and geometrical complications will certainly occur.

Unless the software is designed in BIM software every component and additional metadata will have to be identified and linked within the model before evaluation can begin.

To use Rhino and Grasshopper for this task is perhaps not the best alternative because of the extent to which such a program must encompass massive calculations and organisation of data.

Exemplification

Evaluating the levels of patient safety on a medical ward in a proposal for a new hospital.

The user of the program initially marks the evaluation parameters related to the topic of patient safety and medical wards together with an indication of the required level of score.

The user is now prompted with the field in which metadata is to be specified; functions, patient demographics, work routines, number of staff, type of disease, etc. related to each category.

Having done this, the application runs the individual evaluation on all the parts of the model.

A list of complication areas and topics emerge along with a list of "passed" evaluations. A list of references on the compromised areas is provided. Additional is a list of suggestions to improvements along with an indication of relations between categories.

It is now up to the user to prioritise whether or not changes are to be made.

8.4 Sur-

THE SURVEY IS directed towards employees of architectural companies with speciality in healthcare architecture, design and planning.

The survey is a part of the empirical foundation of the project and to be able to establish the valid arguments for the direction of the tool development a survey upon the 3 scenarios is conducted in cooperation with the architectural firm Friis & Moltke. Selected data as well as comments made by respondents are used in the project.

Following are the three general goals of the survey:

+ To acquire valid statements on scenario choice from professionals

+ Identification of inconclusive areas, further explanation needs and specific development cases.

+ 3.Indication of potential usability of tool functions.

Topics

Following are the three main categories that the survey questions; Design processes, Evidence-based design, Technology & applications.

Design processes

Every architect and firm has his/its own and shared tools, routines and methods used in design phases. How is common ground found and how can the tool be designed to match the needs? How is the design assessed and evaluated?

Evidence-based design

The demands on evidence-based design require that the architect expand his knowledge and experience. How can this be done and to what relevance is this to the architect?

Technology & applications

The use of technology and advanced computer applications is increased in the architectural profession. What are the architects' attitudes towards this? The problems, needs and future perspective are sought through the survey to create a foundation for the technical implications that the tool might have and how to design it.

The results are used in research of innovative design and work processes of architects with focus of future implementation of technology assistance and assessment in healthcare buildings.

Method:

Setup

Test

Approval

Execution

Evaluation

Setup of survey

User group: Architectural firm, Department of healthcare architecture

Number of participants: 3

Areas of interest:

+ Healthcare architecture

+ Design process and decision-making

+ Use of technology in architectural work process

Questionnaire and survey test

The survey is tested before visiting the architectural firms. The questionnaire is approved beforehand by qualified personnel; in this case the supervisors of the project.

The survey test is conducted on four architectural students all writing their individual thesis at Architecture & design within the field of Healthcare architecture.

Test learning and alterations

Results from the test show that too many categories in questions S2, S3 cause confusion. Categories that overlap in topic are removed. Category f) in S3 is added as consequence of the test comments. S7 is expanded to encompass b) age and c) Computer experience. The order of value is reversed to ease the calculation of the results in the evaluation process.

Execution of survey

As explained in [Methodology, p. XX] the survey consist of four phases; 1) Presentation, 2) Discussion session, 3) Questionnaire and 4) Evaluation.

Presentation

The presentation is done at Friis & Moltke with representatives from their healthcare department. It is designed to ensure that the respondents understand the project to full extent as well as shedding light upon the contexts that the project operates in. The presentation using a combination of slideshow and table drawing is chosen to create a more intuitive explanation, a space for more detail discussion and open up for participation of the architects in case some elements need to be clarified.

Discussion-session and questionnaire

After drawing further discussions invite suggestions and alterations before the questionnaire is executed. The reviewer is present in the room so that questions regarding the questionnaire and procedure can be answered ensuring a more effective questionnaire.

Results

Discussion and feedback

The following statements can be found in the recorded audio file [CD, Survey01, Recording01]

+ Friis & Moltke spend more effort on design, sketching and detail design in the construction design phase, and the phase segregation as presented is to deterministic and rigid.

+ There is a need for quality control in the ideation phase of the project.

+ The architects need a tool to sort the information.

+ Too much interface information and user choices in the programme will affect negatively on the usage of the tool, e.g. the company's experience with LUDOC, an IT-tool used to describe the building design information.

+ The benefit of the tool is increased if used on concentrated tasks.

+ The tool should have the building developer as a user in the judgement of different projects. That the tool then will have the role as a common accreditation and assessment utility so that the architect will have to imply in his design phase.

+ The evidence used in the design is culture specific.

Questionnaire

The results of the questionnaire can be read in the diagrams. Following is the formulated evaluation of the results

S1:
Two of the respondents choose scenario A and one respondent chooses scenario B.

S2:
Of the categories the most important is the connection of knowledge in the specific task that the architects work with. Following is the assessment of the design solution and the impacts that it will have on the project. Topics as support in design decisions and user participation are an important factor too.

S3:
Of the possible categories the limitation of the creative process is prominent together with the interpretation of the tool being too rigid to be used in the design process. That one respondent feels that the tool lacks relevance in line of work might have something to do with company organisation and how specific task are handed out to the employees.

S4:
Of the areas that should have the highest development priority is that of the sharing of knowledge and results in the design process and the guidelines between architectural elements and knowledge. Next to these is the implementation of technological functions in the design process.

S5:
Two of the three respondents believe that there is a demand for such a tool in the near future.

S6:
The respondents all think they will use the tools as proposed on a regular basis.

S7:
The respondents' age and experience with computers are spread out through the categories. The specific answers will be used in comparison if needed later in the process.

S8:
All respondents are architects.

Evaluation

Prior to the interpretation, calculation and evaluation of the results of the survey the following sources of errors have been identified and are taken to account in the following section:

+ The casual differences in the execution of the test and the final survey affect a potential comparison of data

+ The difference between the routines, values, emotion and mindset between students and employees is a significant erroneous factor when comparing data and comments.

+ The small number of respondents affects the reliability and validity of the survey results.

+ The feedback situation at Friis & Moltke took a turn in focus toward the very early stages of design. This might have shifted the individuals' mindset in the questionnaire, affecting the choices made.

The results of the survey are evaluated to determine if the initial goals are met.

+ To acquire valid statements on scenario choice from professionals.
Indication is made towards scenario A and scenario B. The issue of concern regarding the scenario

is mainly that of connection of knowledge to decision-making, support in decision-making and assessment of the expected impact that a design will have.

The respondents choose limitations of creativity, rigidness of digital applications and lack of relevance as the main reservations. What is important to notice is, that none of the respondents list cooperation or top-down management as a factor they think as a negative issue of the tool.

+ Identification of inconclusive areas, further explanation needs and specific development cases. Emphasis on the further development is on information control, sharing of knowledge and development of guidelines to be implemented in the design phase. The respondents do not list limitation of control of the individual, which corresponds with the answers made in reservations concerning top-down management. Areas such as separation of technology and creativity, use of the computer for creative processes are neither checked which does not equally correspond with the reservation issue of limitation of creativity.

+ Indication of potential usability of tool functions. The respondents agree to the fact that there is some demand of a tool to meet the needs and criteria of the near future in the building industry. As to the frequency of usage all respondents expect the use of the tool to be on a regular basis.

Reliability, validity and comparison

On basis of the answers the overall goals of the survey have been met. As to the question of reliability the small number of respondents poses an issue as to what extent the derived conclusions and statements of the survey can be accepted as accurate. By having the discussion session, emphasis is made on ensuring that the content has been correctly understood, the respondents had the best informed approach ahead of the execution of the questionnaire and the possibility to get quality feedback from respondents more elaborate than that of the categorised answers of the questionnaire. The shift towards the in-depth focus since broad representation is absent is meant to increase the reliability of the s urvey.

When it comes to the validity of the survey the number of respondents is too small in order to assess whether or not the results are valid enough to represent the general user group profile. As to this project the results still give direction towards possible areas of issue, interest and development, and is therefore used to further the project.

To do this the test results of the student group is involved. The questionnaire being different in setup and order affects the interpretation of results in some questions. Where variations have been distinct the results have been excluded from the further use.

The test group choose scenario B as preferred model. The test group share most of the conditions with Friis & Moltke but there is significant change in the rating of the assessment of design and impact and the integration of evidence-based design. It is fair to assume that being students the test group is more prone to the idea of rating and grading results and tasks as well as the major focus on use of evidence-based knowledge and experience. The focus on use of evidence in architecture is a fairly new discipline, presently being taught at the university and a part of their present student projects. The company employees have other and less research-based criteria for their work. The educational method also plays an important role in the approach to architecture, but since the test group represent the potential of the next generation of architects their indications are taken into account.

The two survey groups agree on computers and applications being a potential limiting factor of creativity and, that digital tools might pose a too deterministic approach within the field of architecture and design.

On future development areas the two groups generally agree. The majority of the student test group foresee an extensive demand of evaluative assessment tools and a regular to frequent individual intentional use.

Revised tool diagram

On behalf of the results and the feedback of the survey and the scenario proposals the tools definitions of user group, technology, context and task are revised.

+ The user group encompass the building developer ahead of the engineer and specialist group.

+ The basic functionalities are preferred to be able to steer, control and maintain goals and tasks of the project as well as ease communication across professions.

+ Linkage between utilities and evidence-based information is weighed as functionality.

+ Enhanced possibility to use the tool across a wider range of the projects phases, from sketch to detail.

+ Enhanced user participation through visual sketch and immediate assessment response by using CAD sketches.

+ Because of rigidness in analysis software and limitation of creativity the ability to toggle the evaluation functions and feedback on and off is an option.

+ The functions should declare to which level of consistency he must obey the feedback, being either guidelines or rules.

The revised tool diagram poses indications towards the tool prototype design later in the project. This is explained in [Tool design, p.xx].