

# DESIGNING A NICU

An Architect's Toolkit for Designing a High-Technological  
Intensive Care Unit on Basis of Healing Environment Principle

---

**AR3AE012 MSc Architectural Engineering**      Joost van de Ven, 1353411

14-06-2015



**Keywords:** Hospital architecture, Healing Environment, NICU, healthcare

front page illustration: 3D view of Room Configuration NICU UZ Leuven (DJGA, 2009)

June 2015  
Research paper  
Graduation studio  
Architectural Engineering

Paper submitted in partial fulfilment of the requirement  
for the degree of Master of Science (MSc) in  
MSc Architectural Engineering

Faculty of Architecture  
Delft University of Technology



**Design Mentor**  
M.J. Smit  
m.j.smit@tudelft.nl

**Faculty Architecture**  
Julianalaan 134, 2628 BL Delft  
PO-box 5048 2628 CN Delft

**Research Mentor**  
A. Koutamanis  
A.Koutamanis@tudelft.nl

2600 GA Delft  
T: +31 (0)15 27 89111  
Fax: 015-2787966



# Preface

This is my research paper for my graduation at the Architectural Engineering studio of the TU Delft faculty of Architecture and the Built Environment. The research paper proposes design directives by which an architect can foresee on the design for the new built and retrofit of a Neonatal Intensive Care Unit (NICU) for an academic hospital. The paper is intended to function as a preparation and preliminary research to facilitate my graduation design. I would like to thank in particular for the guidance Arnold Sikkel (EGM Architecten). Moreover, I would like to thank for the interviews Maurits Algra (DJGA Architecten), Hans Kalkhoven, (Atelier Pro) and Onno Valk (AMC). Lastly, I would like to thank my design mentor Monique Smit for her guidance and my research mentor, Alexander Koutamanis, for steering the research.

Amsterdam, 14 June 2015

Joost van de Ven

Joost (J.P.) van de Ven MSc  
MSc student Architectural Engineering  
Delft University of Technology  
Studentno. 1353411

A Edisonstraat 2/2  
1098 SX Amsterdam  
M +31 (0) 630890333  
E [j.p.vandeven@student.tudelft.nl](mailto:j.p.vandeven@student.tudelft.nl)  
LI <http://nl.linkedin.com/in/joostpietervandeven>

# Abstract

This research is an attempt to awaken the interest of architects for the complex architectural design for healthcare. This into-depth research into a spatial/architectural optimisation of a Neonatal Intensive Care Unit (NICU) brings about the complexity of designing such a facility. Newborn intensive care is care for critically ill newborns that require constant nursing, complicated surgical procedures, regular respiratory support, or other intensive interventions. Being transferred from the mother's womb to the intensity of a neonatal unit can be overwhelming for an infant, especially one who is premature and has not fully developed yet. Therefore, this research paper proposes design directives for a NICU design that can be used by an architect to formulate a programme of requirements that addresses emotional, physical, developmental, medical and social needs for infants, families and hospital workers

The research takes the concept of 'Healing Environment' as a starting point for creating an architectural design for a facility that serves the needs for optimal care for patients, family and staff. Healing Environment (in US: Evidence-Based Design) starts from the notion that the effects of the physical environment affect the healing process and well-being of the patient and health care staff. Technical and spatial directives for a NICU design on basis of Healing Environment can be derived from the objectives (set out in Healing Environment literature) and constraints (presented by precedents). From this, a spectrum of design options can direct the architect in finding an architectural solution.

For the concept principles of Healing Environment, which are categorised by "Themes for the Quality of the Built Environment", this research paper addresses spatial and architectural design options on basis of "Recommended Standards for Newborn ICU Design". Results are shown by theme, and in the discussion themes are aggregated to show where the foremost conflicts in technical and special requirements are apparent. From this, in the second chapter, the different themes are highlighted on layouts of existing NICU floors, to explore how these were facilitated in the building configuration, in order to judge them on satisfying the principles of this healing environment.

In the third and last chapter, both literature study and precedent study are combined and, for the conflicts found in literature directives are compiled. Issues of objectives that conflict (i.e. acoustic comfort versus daylight/safety, routing and logistics versus privacy, safety and security, temperature and air quality versus routing and logistics) can be ordered on a scale which presents what spatial or technical solution fits best for the particular room, configuration of rooms or zones.



Treatment of a newborn in an incubator (University of Connecticut Health Centre, 2009)

# Table of Contents

Preface	3
Abstract	4
Introduction	6
Healing Environment	6
Context	6
Users	7
Problem Statement	9
Research Objectives	10
Research Question	10
Scope	11
Research Methods	12
<b>Chapter A: Essentials for NICU comfortability</b>	
Introduction	14
Quality Themes	14
Results	
A. Acoustics	15
B. (Day)Lighting	18
C. Air Quality	20
D. Temperature	22
E. Comfort, Sensoric Quality	24
F. Hygiene	26
G. Safety	28
H. Orientation, Routing, Logistics	30
I. Privacy, Autonomy	32
Discussion	34
Conclusion	35

<b>Chapter B: Configuration of An Optimised NICU Architectural Layout</b>	
Introduction	37
Reference Projects	38
Results	
A. Acoustics	40
B. (Day)Lighting	41
C. Air Quality	42
D. Temperature	43
E. Comfort, Sensoric Quality	44
F. Hygiene	45
G. Safety	46
H. Orientation, Routing, Logistics	47
I. Privacy, Autonomy	48
Discussion	49
Conclusion	49
<b>Chapter C: Directives for a NICU Design</b>	
Introduction	51
Results	
Acoustic comfort versus daylighting/safety	52
Routing and logistics versus privacy, safety and security	53
Temperature and air quality versus routing and logistics	55
Discussion	56
Conclusion	56
<b>Chapter D: Example Programme of Requirements</b>	
Directives	58
Final Conclusion	61
Research in Perspective	61
Limitations	62
Further Research	62
Literature List	63
List of Figures	64



responsive lighting design solution for the delicate needs of a critical care environment (Shoji & Saito ,2014)

# Introduction

In current hospital buildings, great challenges for contemporary health care materialise: an incremental demand for complex health care that delivers high quality at an affordable price (Grift & Velden, 2013). As such, concepts of architectural layouts for hospitals have become obsolete: these are based on traditional configurations, which do not account for current challenges in health care (Evitts, 2007).

This research focuses on the challenges for designing a new Newborn Intensive Care Unit (NICU). Newborn intensive care is care for critically ill newborns requiring constant nursing, complicated surgical procedures, regular respiratory support, or other intensive interventions (Hardy, 2005). Presently, the NICU population is increasing attributable to recent social and demographic trends such as teenage pregnancy, technological advances in neonatology, and fertility medicine techniques causing multiple births and low birth weight neonates. As a result of the increased use of NICUs, many hospitals are remodeling their facilities (Hardy, 2005).

## Healing Environment

In the past decennia, the effects of the physical environment on the healing process and well-being have proved to be increasingly relevant for patients and their families as well as for the medical staff (Huisman et al., 2012). However, Evidence-Based Design (EBD) does not play a dominant role in the architecture of hospitals (van den Berg, 2005).

The movement towards EBD in healthcare started with Ulrich (Ulrich et al., 2004), who compared the positive effect of views of natural scenery on the recovery of patients from surgery to patients in similar conditions who were exposed to a view of a brick wall. Ulrich showed that in comparison with the wall-view group, the patients with the tree view had shorter postoperative hospital stays, had fewer negative evaluative comments from nurses, took fewer moderately strong and strong medication, and had slightly lower scores for minor postsurgical complications (Huisman et al., 2012). Since then, the impact of the physical environment of the hospital on the well-being and health of the patient has received extensive academic attention. Consequently, this resulted in a creation of spaces considered to be healing environments. An increasing body of knowledge on evidence-based healthcare design has become available, and the amount of information has grown rapidly in recent years.

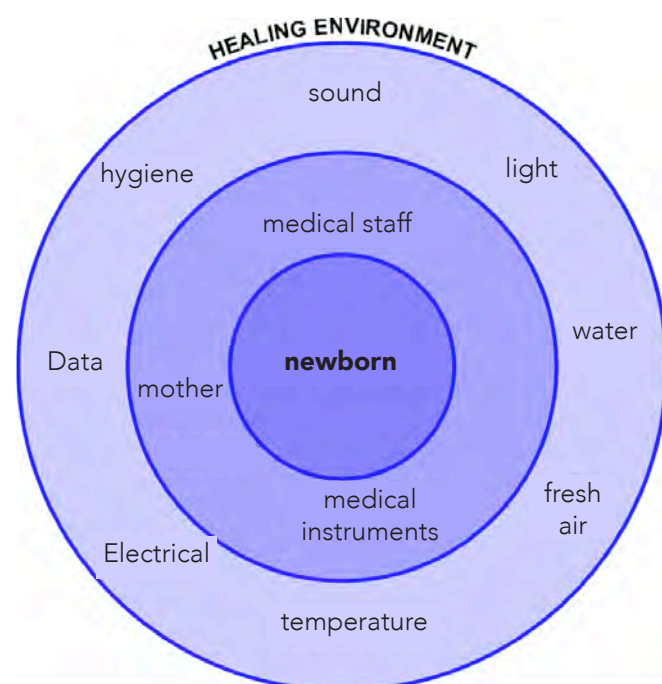
However, decision makers have questioned the quality of the available evidence for health impacts of healing environments (van den Berg, 2005). Thus, if evidence-based design is going to revolutionise the architecture of hospitals, it will first have to bridge the gap between traditional and institutionally designed healthcare facilities relative to the actual well-being of patients as an indicator of their health and recovery.

This research paper aims to contribute to finding tangible grips for architects to grasp on the concept of healing environment for designing a (department in) a health care facility.

# Context

The incorporation of the single-family room (SFR) into the design of neonatal intensive care units has been a recent paradigm shift (moving from the previous open ward rooms) and focuses first and foremost on the developmental needs of critically ill or extremely premature infants (Cone et al., 2010). The popularity of this design has been attributed first and foremost to the ability to control harmful environmental stimuli deemed detrimental to the critically ill or preterm developing neonate. In addition, the SFR design enhances privacy, is conducive to breastfeeding and kangaroo experiences for families, is in keeping with the hospital wide trend to private rooms for all other patients, and is congruent with efforts to enhance infection control (Harris, D., Shepley, M., White, R., Kolberg, K., & Harrell, J., 2006).

Although the SFR design has noted advantages, physicians, nurses, and interdisciplinary team members who are unfamiliar with this concept of care may be skeptical as to the opportunity to enhance the physical environment for the betterment of infants, families, and staff alike. Of necessity, moving from the “Baby Barn” to the SFR unit involves considerable change in the physical environment. The isolation of neonates in separate private rooms prompts concerns about the relative safety of the SFR compared with the open-ward design (Domanico et al., 2011). The desired control of harmful stimuli does indeed employ changes in design that increase the possibility of isolation and separation of the patient and caretaker. In an effort to offset these concerns for isolation, further changes are put in place. Enhanced technology as well as changes in socialisation and work-flow patterns are invoked to offset these potential and real concerns. If a unit is not designed with a great degree of forethought, deleterious situations can arise and contribute to staff dissatisfaction and turnover, to say nothing of patient safety issues (Ulrich et al., 2004).



Aspects of Healing Environment Influencing the Newborn (van den Berg, 2005)



# Users

## Patient: Newborn

In referring to NICU children the parent-friendly term “newborn” is used rather than the clinical term “neonatal” (Smith et al., 2003). Being transferred from the mother’s womb to the intensity of a neonatal unit can be overwhelming for an infant, especially one who is premature and has not fully developed yet (Bird et al., 2011). The size and maturity of newborn infants make them uniquely susceptible for injury, even with the slightest deviation in safety practice. Thus, there should never be any room for error in the care of newborn infants (Raju et al., 2011). For preterm or ill newborns, the vital functions immediately after birth are the primary concern of health-care professionals, often overriding physical contact with the mother (Niela-Vilén, 2013). Newborns should be closely and frequently monitored to be sure they achieve optimal growth, to correct delays in growth, and to avoid the risk of excessive intake (Hashim & Guillet, 2002). Consequently, the first physical contact with mother usually actualises later.

## Patient: Mother

Mothers experiences of becoming a mother in the NICU were conceptualised by Heermann et al. (2005) as a developmental process from outsider to engaged parent. This process of maternal development occurred in four domains: focus, ownership, caregiving, and voice.

During the first experiences in the NICU, many mothers appeared to be totally overwhelmed by the technology of the unit and the expertise of the nurses (*focus*). The technology of the NICU and the fragile, tiny appearance of the infant could serve as a barrier to the mother’s sense of her *ownership* of the baby. As they became more comfortable in the NICU and as their babies’ medical conditions improved, they were more likely to “claim” the babies as their own: mothers engaged in maternal *caregiving* actions along a continuum from passive to active *voice*. Caregiving actions included touching, soothing, and holding as well as physical care (for example: feeding, bathing, positioning, and diapering) During infant’s hospitalisation, the importance of physical contact between mother and her infant has been strongly stated (Nyqvist et al., 2010, WHO, 2003). Preterm infant’s physical contact with the mother, known as kangaroo care, is implemented in the NICU after the primary resuscitation and when the infant’s condition is stable enough. . When mothers became engaged parents, they were ready for partnering. Partnering required not only maternal engagement with the baby but also family focused care by nurses. (Heermann et al., 2005)



Contact with the Newborn in an Incubator  
(Community Memorial Hospital, 2008)

## Family

The physical appearance of the environment, including the high-tech equipment (Miles, Funk & Kasper, 1991) and high temperature (Raeside, 1997) may intimidate and undermine families. The Neonatal Intensive Care Unit (NICU) environment has the potential to exacerbate stress for parents of infants admitted to the NICU for reasons other than prematurity or low birth weight. NICU stressors, individually or in combination, may interfere with the parent–infant relationship and create extra difficulties for the couple and wider family (Carter et al., 2007). Miles (1989) has identified four specific aspects of the NICU environment that have the potential to be highly stressful for parents. These sources of stress include the NICU physical environment, the infant's physical appearance and behaviour, staff and parent interactions, and alterations in the parent role (Carter et al., 2007).

Therefore, Family-Centered Care is becoming a standard of care in NICUs (Cooper et al., 2007). Viewing the family as the child's primary source of strength and support, this philosophy incorporates respect, information, choice, flexibility, empowerment, collaboration and support into all levels of service delivery. Regarding family-centered care, it is well documented that parents in NICU settings suffer a high level of stress (Goldson, 1992).

## Medical Staff

Medics in NICUs operate in a challenging environment with the demands of care of the infant and providing family-centered care. There is a need for nursing support to assist parents of ill infants. Medics are in a position to influence caregiver's abilities to cope with stressors and to become effective parents (Hunt, 2011). Interpersonal communication is one principal tool used to trade information between health professionals, patients, and families (Jones, Woodhouse, & Rowe, 2007). Nurses above all, are a primary source of support for parents during this difficult transition from the NICU to the home. Moreover, medics in general are the primary educators in teaching parents and caregivers how to care for their premature infant (Jones, et al., 2007).



Surgery in a NICU Operative Room  
(Bon Secour Health System, 2015)

# Problem Statement

Being transferred from the mother's womb to the intensity of a neonatal unit can be overwhelming for an infant, especially one who is premature and has not fully developed yet. Lighting and acoustical quality are of particular importance, as are basic design principles such as layout and location and family and visitor comfort (Bird, Bostic, Taylor & Zhou, 2011). Above all else, the way NICUs are laid out affects the health of the infants who are in the unit. The infants are often some of the most vulnerable patients in the hospital; therefore the design of the wards needs to allow them to conserve their energy and make it as easy as possible for caregivers and health professionals to help the infant in whatever way is needed (Bird et al., 2011).

The desired control of noxious stimuli does indeed employ changes in design that increase the possibility of isolation and separation of the patient and caretaker (Cone et al., 2010). If a unit is not designed with a great degree of forethought, deleterious situations can arise and contribute to staff dissatisfaction and turnover, to say nothing of patient safety issues (Zimring, Joseph & Choudhary, 2004).

It is thought that by transforming toxic work environments into healthy workplaces demonstrable effects may be seen on retention, recruitment, job satisfaction for all health care staff, and patient outcomes—particularly those related to patient safety (McCauley & Irwin, 2006). Environmental conditions in NICUs are of the utmost importance considering the relationship they have with health and development. This problem statement distinguishes between “Themes for the Quality of the Built Environment” on basis of the research “*Onderzoek Aantrekkelijkheid Zorgomgevingen met behulp van de Impact Scan* (Eng.: Research Appeal Health Care Environments using the Impact Scan)” (TNO,2009):



## A. Acoustics

“The NICU is often characterised by loud, unpredictable noise from extraneous sources such as alarms, ventilators, phones and staff conversation to which preterm infants are especially vulnerable” (Wachman & Lahav, 2010).



## B. (Day)Lighting

“Light impacts human health and performance by enabling performance of visual tasks, controlling the body's circadian system, affecting mood and perception, and by enabling critical chemical reactions in the body.” (Joseph, 2006)



## C. Air Quality

Ventilation may improve people's health in several ways: by providing air for breathing, by removing and diluting indoor pollutants, by adding or removing moisture, and by heating or cooling the indoor environment. Ventilation may also have harmful effects on indoor air quality and climate if 41 contaminated air is sucked in (Seppänen & Fisk, 2004).



## D. Temperature

The neonatal IC unit thermal environment must support thermally fragile infants and mature adults including caregivers, parents, and other support personnel. Nurses in NICU raised concerns about variability of room temperature, particularly in relation to seasonal outdoor temperature and weather conditions (Thomas et al., 2010).



## E. Comfort, Sensoric Quality

Early physical contact (skin-to-skin), factors promoting early physical contact (promotion of early interaction, or promotion of breast feeding) and impeding early physical contact improve the sensoric comfort of the neonatal infant (Niela-Vilén, 2013).



## F. Hygiene

It is well established that hand hygiene is the most important single measure for preventing the spread of pathogens in healthcare settings (van Roosmalen, 2009). In this context, the fact that hand-washing compliance rates are often low represents a very serious challenge to patient safety.



## G. Safety

Patient safety issues are NICU systems design, working conditions, and worker fatigue leading to errors during resuscitation, mechanical ventilation, and performance of invasive procedures; medication errors including those associated with milk feedings; diagnostic errors; and misidentification of patients (Raju, Suresh & Higgins, 2011).



## H. Orientation, Routing, Logistics

The layout of the space should support, not hinder, their activities (Shepley, 2002). Nurses spend an incredible amount of time walking back and forth from the NICU and other main hubs such as the nurse's station, increasing the time that it takes for them to perform tasks and decreasing their comfort and productivity at work.



## I. Privacy, Autonomy

The crowded setup of a NICU facility leaves little room for privacy or personalisation of space to meet the needs of the infant and the family (Pineda et al., 2012).

# Research Objectives

Design strategies for NICUs need to address emotional, physical, developmental, medical and social needs for infants, families and hospital workers (Bird et al., 2011). The research objective for this research paper is to link all analyses on healing environment carried out in academia with spatial design variants of existing NICU floors, in order to judge them on satisfying the principles of this healing environment. This will provide with directives that accomodate technical and spatial requirements that need to be set for a NICU, as such that an architect can compile a programme of requirements.

**MO** | *to judge spatial design variants of existing NICU floors on satisfying the principles of healing environment from literature.*

Different types of research aim to research different aspects of the NICU design:

- Ch. A - literature study:  
to find what the technical and spatial requirements are, that can be deduced from the 'principles of healing environment' (on basis of Role of the Physical Environment in the Hospital of the 21th century (Ulrich et al., 2004)) which can be affected by the spatial and architectural design of the architect.
- Ch. B - precedent study:  
to find how the technical and spatial requirements were embodied in the spatial and architectural design of previous (existings) NICU facilities on basis of study of the architectural layout and interviews for confirmation of the researcher's interpretations.
- Ch. C - Directives:  
to unfold design options (directives), which can be used by the architect as a starting point in making an architectural design for NICU.

# Research Question

This research paper focuses on answering the following main research question:

**MQ** | *"How can a NICU design be made, in which the architect foresees on technical and spatial requirements to create an architectural design based on the principles of Healing Environment?"*

The following subquestions are introduced to serve the objectives of the different chapters

**SQ1** | *"What technical and spatial **objectives** that serve a healing environment conflict in an architectural design for the NICU?"*

**SQ2** | *"How are the subsequent technical and spatial **constraints** embodied in precedent designs for NICU?"*

**SQ3** | *"How can consequently technical and spatial **requirements** be translated into a visual Programme of Directives?"*



# Scope

The scope of this research compounds the technical and spatial requirements that relate to the embodiment of the “Themes for the Quality of the Built Environment” (TNO, 2009), as shown in the problem statement. These themes are researched for the following rooms/spaces (Laing, Ducker, Leaf & Newmarch, 2004) :

Clinical Rooms	
intensive care room	Room for care for medically unstable or critically ill newborns requiring constant nursing, complicated surgical procedures, continual respiratory support, or other intensive interventions (White, 2012).
high dependency room	Room where patients can be cared for more extensively than on a normal ward, but not to the point of intensive care
special care room	Rooms which are allocated to special care, and which are not to be used at any time for intensive care functions
Transitional care	In this facility, parents can look after their own infants with some supervision from trained Neonatal Unit staff.
Resuscitation	Eachw room should therefore have a designated area for resuscitation containing an open radiant-heated cot or resuscitaire, with appropriate facilities
Inpatient treatment room	A tertiary referral centre requires a treatment room to carry out laser therapy for retinopathy of prematurity. The room should be fully provided for intensive care.
Outpatient treatment room	Many NNUs offer a daily “drop-in” clinic for unscheduled patients. An outpatient treatment room can be placed close to the NNU entrance,
Laboratory	Near patient testing is essential for the progressive Neonatal Unit. It is standard to be able to test examples within the confines of the Neonatal Unit
Pharmacy	Many Units are served by a central Pharmacy in the hospital. A central room can be used for preparation of drugs.

Administrative Work Areas	
Reception	the organisational centre of the unit: here families are greeted, telephone calls are received, specimens are up-lifted, results delivered, and letters are sent and received.
Unit Office	Next to the Reception Area, the Unit Office will be one of the most frequently used areas of the Neonatal Unit and therefore deserves extra planning according to the Unit's needs.
Supporting Offices	Every Neonatal Unit needs to be supported by dedicated staff offices. In these, members of staff or relatives can have confidential discussions with senior staff.
Seminar room, meeting room and skills lab	In small Neonatal Units seminars and meetings may be held in the same room. In large Units two separate rooms are required.
Library	The library should have extensive shelving containing medical and nursing textbooks and journals. There should be two work- tops with two work stations in each. All four computers should have Internet connections.



NICU L-Shaped Layout (Aspirus Wassau Hospital)  
(McCuskey Shepley, 2014)

# Research Methods

The research can be seen as *descriptive*, *explanatory* and *exploratory*. Inputs for these types of researches are distinct, as it uses diverse types of evidence as in case-study research: literature, precedent study and interviews (Yin, 2003). Methodological triangulation is used, in which one approach is followed by another, to increase confidence in the interpretation and to find different aspects of the research subject from different types of evidence (Denzin, 1984).

## Literature Review

A precedent study needs validation from literature, to support the chosen research methods and construe key variables, linkages and relationships between spatial and architectural design options. This research paper addresses spatial and architectural design options on basis of the “Recommended Standards for Newborn ICU Design” by White (2012). This guideline introduces recommendations that apply to the newborn intensive care built environment, although most have broader application for the care of ill infants and their families (White, 2012). It is intended to provide guidance for the planning team to apply the functional aspects of operations with sensitivity to the needs of infants, family and staff.

The recommended standards are cross-linked with findings in academia regarding principles of Healing Environment (in the US referred to as Evidence-Based Design). The concept of healing environments includes that the physical environment in health-care can create a difference in the recovery rate of patients, or how fast the patient adapts to acute and chronic illnesses (Stichler, 2001).

## Precedent Study

A precedent study is done by means of researching the existing Neonatal IC Units of the *Wilhelmina Kinderziekenhuis (UMC Utrecht)*, *Ikazia ziekenhuis*, *UZ Leuven* and *Maxima MC Veldhoven*. This is done by means of scrutinising the layouts (obtained from the architects) and researching published papers. Because there is very limited academic research that address the architectural design of a Neonatal Intensive Care Unit, by means of doing analyses of precedents this research intends to exhibit the implicit design choices made. Using the literature research, it is assessed how these Neonatal IC Units score on the different themes for the quality of the built environment (TNO, 2009).

As Franck (2013) explains, the use of precedent studies is threefold:

- Precedent studies can lend authority to the design, by equating it to something which is already accepted in the built environment.
- Precedents can create meaning in the design, for the researcher, the public, or the client
- Precedents can show examples of how to solve specific problems in plan, section, elevation and detail.

## Interviews

Interviews with the architects from the precedent Neonatal IC Units provide with explanations of how certain design choices were made, and what were the considerations behind it. It brings forward key aspects found in the design of Neonatal IC

Units, that from an architectural viewpoint rarely have been documented and evaluated. For this study, it is chosen to apprehend the open-ended interview in the first place. Focused question will be addressed, yet the discussion is open for introduction of new topics.

Interviews were held with:

- Arnold Sikkel, architect director EGM Architecten
- Maurits Algra, architect director DJGA Architecten
- Hans Kalkhoven, (former) architect Atelier Pro
- Onno Valk, property management AMC hospital

## Plan Validity

Yin (2003) names 4 types of validity: construct validity, internal validity, external validity and reliability.

- Construct validity points at using correct operational measures, which will need to be checked for.
- Internal validity describes causal relationships, that are a requirement for validity in explanatory or causal studies, but not in exploratory studies.
- External validity means that the research results can be extrapolated to other fields. This type of validity is not the intended aim, however a bigger application of found conclusions do validate the research as being useful.
- Reliability describes the option of reproducing the research and come to the same results.

Below it is described how validity is accomplished:

Part A	Literature study	External validity
Part B	Project documentation	construct validity, internal validity
Part B	Interviews	Internal validity, reliability
Part C	Participant observation	External validity

## Limitations

The directives are intended for use by an architect for designing a NICU facility. However, this programme should not be seen as a standard. Instead, this should be interpreted as a guideline. The alleged options for designing a NICU is limited to the researcher's literature research, case studies and interviews. As such, there are many shortcomings:

First, the starting points for this research (i.e. recommended standards for NICU design, Role of the Physical Environment on the hospital of the 21st century) are written by american authors (i.e. White (2012), Ulrich et al. (2006)). However, This research uses these starting points for researching four NICU facilities in the Netherlands. It can be argued that a literal translation from American concepts to a Dutch environment Interviews have produced an internal validation of the above-mentioned arbitrary decisions, and made a contemplation of linkages of analyses (internal validity, reliability) possible. However, these do not go into detail and cannot one-on-one be extrapolated to other projects (external validity).

# Chapter A

## Essentials for NICU comfortability



Mother Central in Patient-Centred Care (Wilson, 2013)

# Introduction

## SQ1

*“What technical and spatial objectives that serve a healing environment conflict in an architectural design for the NICU?”*

This chapter exhibits the different aims of healing environment, found in literature on Healing Environment, that affect the spatial and architectural design of the architect. These aims are distilled from the report for ‘The Center for Health Design for the Designing the 21st Century Hospital Project’ by Ulrich, Quan, Zimring and Joseph (2004) that describes the ‘Role of the Physical Environment in the Hospital of the 21st Century’. In this research the principles mentioned are related to aspects of the built environment suggested in the ‘Recommended Standards for Newborn ICU Design’ by White (2012). Lastly, the findings are categorised by ‘Themes for the quality of the Built Environment’ (TNO,2009). As such, an overview of relations between the Healing Environment and the physical (built) environment is compiled.

The discussion of this chapter highlights the foremost conflicts in the architectural design of a NICU, on basis of the researcher’s interpretation of the different themes of Healing Environment that are intended to comply with. Finally, in the conclusion all key findings are summarised.

# Quality Themes



A. Acoustics



B. (Day)Lighting



C. Air Quality



D. Temperature



E. Comfort,  
Sensoric Quality



F. Hygiene



G. Safety

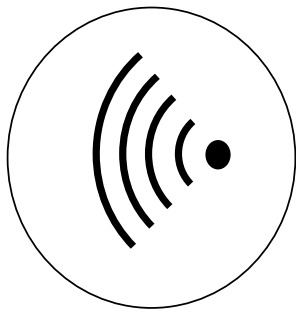


H. Orientation,  
Routing, Logistics



I. Privacy, Autonomy





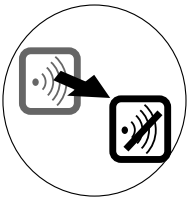


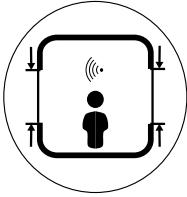

# A. Acoustics









Acoustic Ceiling Elements in the Central Bay of the UZ Leuven NICU (Acoustic Bulletin, 2015)

#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users (White, 2012)
I.A.C	Reducing Noise Levels	higher noise levels are found being stressful (Blomkvist et al., 2004)	All rooms, but in particular: Operative delivery rooms; Labor/Delivery/Recovery (LDR), Post-partum (LDRP) rooms, and non-operative delivery rooms.	Staff
III.A.A	Reducing Noise Sources	Many sources are unnecessary and are loud; hampers rest patients (Ulrich et al., 2003)	All rooms, but in particular: Infant space; Private (Single-Family) Rooms - family space	Patient
III.A.B	Use of sound-absorbing surfaces	sound reflections increase the noise level as compared to space with the same round source but all sound absorption (van Roosmalen, 2009)		Patient
III.B	Improve conditions for sleeping	Disrupting the sleep cycle of the infant should be avoided, because in the sleep some of the most critical growth and cognitive development takes place (Ferris et al., 2013).	Infant space; Private (Single-Family) Rooms - family space	Patient

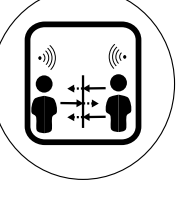

### Recommended Standards For Newborn ICU Design for the Architect (White, 2012):

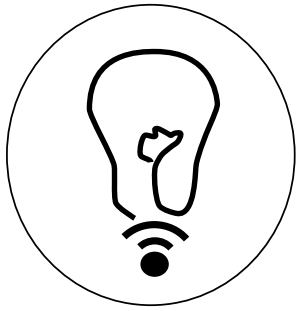
Draft Design				
A.1		<p>In terms of room adjacencies, locate louder rooms, such as <b>Operative rooms</b>, away from patient rooms.</p> <p>NICU operative room (Grand River Hospital, 2012)</p>		
		<p>room: <i>All rooms</i> measure: <i>spatial configuration</i></p>		
A.4		<p>Walls can be built <b>at obtuse angles</b> to dissipate sound.</p> <p>Obtuse Angle (Pinstopin, 2014)</p>		
		<p>room: <i>All rooms</i> measure: <i>interior design</i></p>		
A.8		<p>Glass should be limited to the area actually required for visualisation in order to leave wall surface available for absorptive surface treatment.</p> <p>NICU Double-Room Monitoring (Dignity Health, 2012)</p>		
		<p>room: <i>bedrooms, operative rooms, delivery rooms</i> measure: <i>interior/exterior design</i></p>		

## Preliminary Design

<p>A.3</p> 	<p>Transition surfaces that do not obstruct mobility, are durable, and minimize noise and jarring of equipment should be provided at the intersection of <b>different flooring materials</b>.</p> <p>NICU flooring (Flooring Advisor, 2013)</p> <p>room: <i>Operative rooms, delivery rooms</i> measure: <i>building physics, materialisation</i></p>	
<p>A.5</p> 	<p>Acoustically absorptive surfaces reduce reverberation and, therefore, sound levels at a distance from the sound source. When possible, <b>two perpendicular walls</b> should be covered with sound absorptive surface materials. Where this is not possible the upper portions of all four walls (above areas likely to be damaged by the movement of equipment) should be covered with such material.</p> <p>(Audimute, 2014)</p> <p>room: <i>All rooms</i> measure: <i>building physics, interior design</i></p>	
<p>A.7</p> 	<p>Ceilings can be made of highly-absorbent tiles. They can also have sound-absorbent foam added, and this can be combined with cosmetic advantages e.g. by using foams in the shape of clouds, stars, suns, moons</p> <p>C Max Acoustic Ceiling Tiles (von Parker-Herraud, 2013)</p> <p>room: <i>bedrooms</i> measure: <i>interior design</i></p>	

## Detail Design

<p>A.2</p> 	<p><b>Sound-absorbing panels</b> are principally of vinyl-covered. They can also be hung with washable tapestries or sound-absorbent material. Windows can be partly covered by sound-absorbent blinds</p> <p>Open Space Acoustic System (Acoustic Pearls, 2014)</p> <p>room: <i>All rooms</i> measure: <i>materialisation</i></p> <p>Sound absorbing panels, in the shape of curtains and art boards can be used in order to create a calmer private zone</p> <p>Hospital Quiet Zone (Moeller, 2014)</p> <p>room: <i>bedrooms, family support rooms</i> measure: <i>interior design</i></p>	
--	--	--



## B. (Day)Lighting

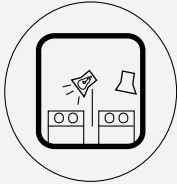

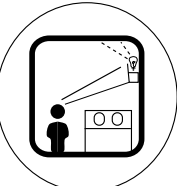

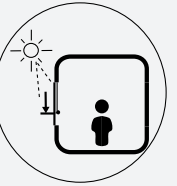

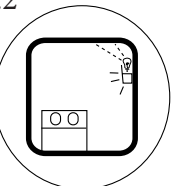

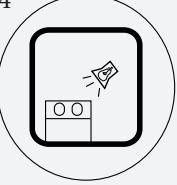



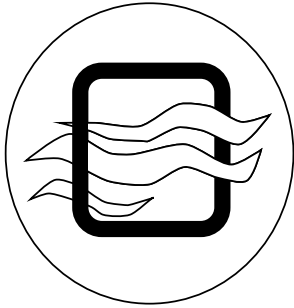
Lighting in Single Family Room (Cooper, 2011)



#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users
II.G.A	Sufficient Lighting Level	guarantee sufficient lighting level, prevent frequent interruptions or distractions during work, and guarantee adequate private space for performing work	Charting/Staff Work Areas, infant rooms	Staff
III.D	Reduce Depression	Daylight i.a. improves health outcomes and less perceived stress (White, 2012)	Private (Single-Family) Rooms - family space, infant rooms	Patient, Staff
III.E	Provide Nature and Positive Distraction	view of nature calms down the patient and reduces stress because of positive distraction, which can result in improved recovery. (van Roosmalen, 2009)	Private (Single-Family) Rooms - family space, infant rooms	Patient

### Requirements for the Architect (White, 2012):

Preliminary Design		
B.5	<div></div> <p>In locations where these functions overlap with infant care areas (e.g., close proximity of the staff charting area to infant beds), the design should nevertheless permit <b>separate light sources</b> with independent controls so the very different needs of sleeping infants and working staff can be accommodated to the greatest possible extent. Separate Light Sources (Harper, 2013)</p> <p>Room: <i>Infant room</i> Measure: <i>interior design</i></p>	
B.3	<div></div> <p><b>No direct view of the electric light</b> source or sun shall be permitted in the infant space: this does not exclude direct procedure lighting. Any lighting used outside the infant care area shall be located so as to avoid any infant's direct line of sight to the fixture. responsive lighting design solution for the delicate needs of a critical care environment (Shoji &amp; Saito ,2014)</p> <p>Room: <i>Infant room</i> Measure: <i>spatial design</i></p>	
Detail Design		
B.1	<div></div> <p>All external windows shall be equipped with <b>shading devices</b> that are neutral color or opaque to minimise color distortion from transmitted light. Shading devices should be easily controlled to allow flexibility at various times of day, and should either be contained within the window. shading devices patient rooms (Gm-design ltd, 2014)</p> <p>Room: <i>Family rooms</i> Measure: <i>materialisation</i></p>	
B.2	<div></div> <p>At least <b>one source of light</b> shall be visible from infant care areas, either from each infant room itself or from an adjacent staff work area.</p> <p>One source of light visible in NICU room (I. C. Thomasson Associates, 2007)</p> <p>Room: <i>Infant room</i> Measure: <i>interior design</i></p>	
B.4	<div></div> <p><b>Separate procedure lighting</b> shall be available to each infant bed.</p> <p>NICU procedure lighting (Shrimad Rajchandra, 2015)</p> <p><i>Infant room</i> Measure: <i>interior design</i></p>	



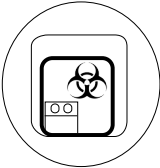


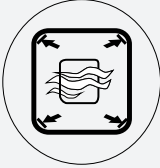
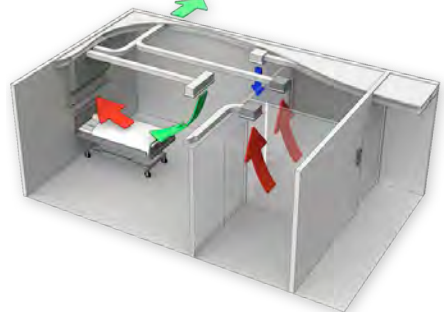
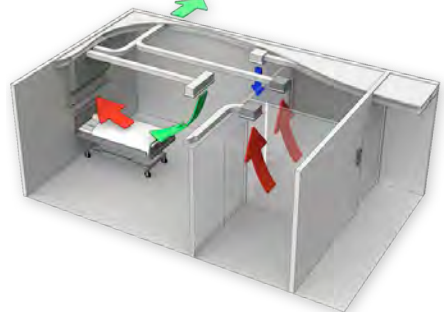



## C. Air Quality



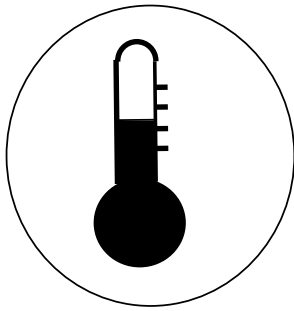
Single-Family Room (2015) Hamilton Health

#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users
I.A.A	adequate ventilation with good maintenance	conventional mechanical ventilation and continuous positive airway pressure times can improve working conditions in the SFR (Domanico et al., 2011)	Airborne-isolation rooms, operative/delivery/resuscitation rooms, infant rooms	Staff
II.A.A	guarantee a good air quality and patients reside in single-bed rooms	Ventilator-associated pneumonia is a common and severe complication in NICU patients (Drews et al., 1995; Gaynes et al., 1996).	Airborne-isolation rooms, operative/delivery/resuscitation rooms, infant rooms	Patient

### Requirements for the Architect (White, 2012):

Draft Design		
C.2	<div></div> <div><p>A space within the NICU should also be available to safely cohort a group of infants infected with or exposed to a <b>common airborne pathogen</b>.</p><p>Airborne-infection isolation room (Renfrew Group International, 2011)</p><p>room: <i>Airborne-infection isolation room</i> measure: <i>spatial design</i></p></div> <td></td>	
Preliminary Design		
C.3	<div></div> <div><p>Airborne infection isolation room perimeter walls, ceilings and floors, including penetrations shall be sealed tightly so that <b>air does not infiltrate</b> the environment from the outside or from other airspaces.</p><p>Clean Room Technology (Howorth Air Technology, 2014)</p><p>room: <i>Airborne-infection isolation room</i> measure: <i>building physics, materialisation</i></p></div> <td></td>	
Detail Design		
C.4	<div></div> <div><p>Specific attention is required, therefore, to the design of <b>noise-attenuating devices</b> in the heating/ventilation/air-conditioning (HVAC) ductwork and to washable acoustic surfaces on the walls and ceilings to ensure that sound levels meet the standard in these rooms.</p><p>Ceiling Air Purification Systems for Positive Pressure (Medical Air Solutions, 2015)</p><p>room: <i>all rooms</i> measure: <i>building physics</i></p></div> <td></td>	





## D. Temperature


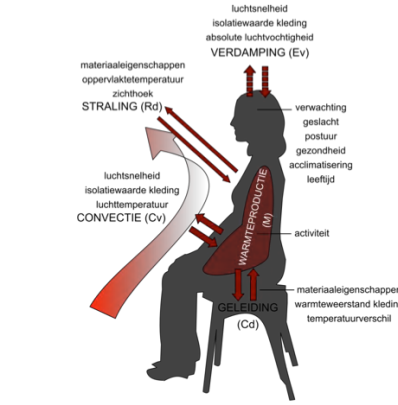
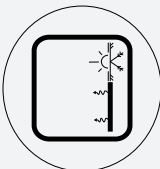
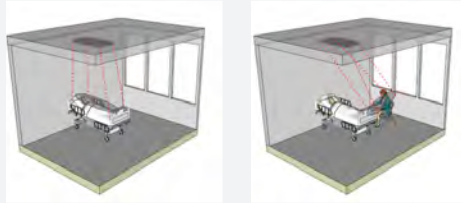


Temperature Comfort in a NICU Room for patient and family (Health, 2015)



#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users
II.J	ambient temperature	Temperature in the NICU has to be higher and more consistent than in other hospital departments, to promote skin-to-skin care (Niela-Vilén et al., 2013)	infant rooms, family rooms	Patients

## Preliminary Design

<p>D.1</p> 	<p>It is essential that the <b>appropriate ambient temperatures</b> can be achieved within a short time frame, since many high-risk deliveries occur with little warning.</p> <p>Heat currents around mother (De Vaan, 2015)</p> <p>Room: <i>brdrooms</i> Measure: <i>Spatial Design, Interior design, building physics, materialisation</i></p>	
<p>D.2</p> 	<p>Heat sources near the exterior wall, if applicable, should be considered to ameliorate “cold wall” condition, which in turn can be a source of convection drafts. This application of heat may also alleviate the conditions leading to condensation on these walls.</p> <p>Radiant heating panel (De Vaan, 2015)</p> <p>Room: <i>bedrooms, family rooms</i> Measure: <i>spatial design, building physics</i></p>	



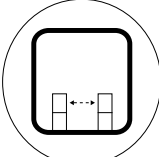

# E. Comfort, Sensoric Quality







Contact with the Newborn in an Incubator (Community Memorial Hospital, 2008)

#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users
I.A.B	Distance to Radiation Medical Equipment	guarantee distance of nursing staff members to radiating medical equipment such as high-intensity surgical-light sources	Operative/Delivery/Resuscitation rooms	Staff
I.A.D	Ergonomic Design Hospital Equipment	ergonomic design of patient beds and nurses' station	Infant, family rooms	Staff
III.F.A	Provide Comfort Zones	providing lounges, day rooms, and waiting rooms with comfortable movable furniture arranged in small flexible groupings	family (support) rooms	Family


### Draft Design

E.1 	There shall be an <b>aisle</b> adjacent to each infant space with a minimum width of 1.2 meters in rooms with multiple incubators.  Infant Room (Terrace, 2012)	
	room: <i>bedrooms</i> measure: <i>spatial design</i>	

### Preliminary Design

E.2 	In order to provide adequate space at the bedside for both caregivers and families, however, these rooms need to be somewhat larger than an infant space in an open multi-bed room design, and they must have <b>additional bedside storage and communication capabilities</b> in order to avoid isolation or excessive walking of caregivers. Interior of Single Family Room (Cooper, 2011)	
	room: <i>bedrooms</i> measure: <i>spatial design</i>	
E.3 	<b>Prevention of vibration</b> in the interior. Vibration is perceptible to humans at a certain magnitude or level and can cause discomfort or annoyance. Sources of vibration common in hospitals are helicopter flyovers and landings/take-offs, magnetic resonance imagers, sound systems, and heavy trucks. Vibration Suspension for Hospital Buildings (Alpha Acoustiki, 2015)	
	room: <i>All rooms</i> measure: <i>structural design, building physics</i>	

### Detail Design

E.4 	A comfortable reclining chair suitable for kangaroo/skin-to-skin care (e.g. lactation support)  Mother and Child Care in a NICU (Wechsler Linden, 2015)	
	room: <i>bedrooms, family rooms</i> measure: <i>interior design</i>	
	There should be comfortable discreet areas for expressing milk. Breastmilk pumps should be widely available for all mothers	
	room: <i>bedrooms, family rooms</i> measure: <i>interior design</i>	



## F. Hygiene






Treatment of a newborn in an incubator (University of Connecticut Health Centre. 2009)





#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users
II.A.B	Hand Cleaning	provide sufficient alcohol-based hand-rub dispensers or hand washing sinks	All rooms	Staff, Family
II.E.A	Placements Hand Cleaning	placement of sinks or hand-cleaner dispensers in more accessible locations (Cohen et al., 2003; Vernon et al., 2003)	Infant, family rooms	Staff, Family
II.C.B	Hand Cleaning Bedside	installation of alcohol-based hand-cleaner dispensers at bedside to improve adherence		Staff, Family
II.F	Guarantee Distance	guarantee distance to an infected patient and shared exposure to caregivers (Jernigan et al., 1996)		Staff

### Preliminary Design

F.1 	Each room shall have a hands-free handwashing station. Handwashing Station NICU (Gutierrez, 2013)	
	room: <i>bedrooms, operative rooms, delivery rooms</i> measure: <i>spatial design</i>	
	Handwashing sinks shall be large enough to control splashing and designed to avoid standing or retained water. Minimum dimensions for a handwashing sink are 24 inches wide x 16 inches front to back x 10 inches deep (61 cm x 41 cm x 25 cm) from the bottom of the sink to the top of its rim.	
	room: <i>bedrooms, operative rooms, delivery rooms</i> measure: <i>spatial design</i>	
F.2 	Handwashing facilities located at a level where they can be used by people in wheelchairs shall be available in the NICU.	
	room: <i>bedrooms, operative rooms, delivery rooms</i> measure: <i>interior design</i>	
	A hands-free handwashing station for hand hygiene and areas for gowning and storage of clean and soiled materials shall be provided near the entrance to the room.	
	<i>All rooms</i>	

### Detail Design

F.3 	handwashing sinks shall be constructed of non-porous material.	
	NICU handwashing (Coverall, 2014)	
	room: <i>bedrooms, operative rooms, delivery rooms</i> measure: <i>materialisation</i>	
	Sink location, construction material and related hardware (paper towel and soap dispensers) should be chosen with durability, ease of operation, ease of cleaning, and noise control in mind. room: <i>bedrooms, operative rooms, delivery rooms</i> measure: <i>materialisation</i>	










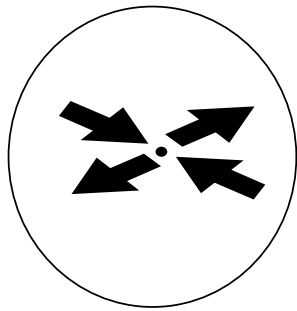
# G. Security, Safety



Corridor Neonatal IC Unit (Christner, 2014)

#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users
II.G.B	Transfer of Patients	prevent the transfer of patients between rooms or different units, because this is a source of medication errors (Cook, Render & Woods, 2000)	All bedrooms	Patients
II.H	Slippery Floors	prevention of slippery floors, inappropriate door openings, poor placement of rails and accessories, and incorrect toilet and furniture heights	Infant, family rooms	Patients, Staff, Family

Draft Design		
<div>G.1</div> <div></div>	<div>The NICU shall be designed as part of an overall <b>security program</b> to protect the physical safety of infants, families and staff in the NICU. The NICU shall be designed to minimise the risk of infant abduction.</div> <div>Overview on the NICU floor (Knight Architects, 2014)</div>	
	<div>room: <i>All rooms</i></div> <div>measure: <i>spatial design</i></div>	
<div>G.2</div> <div></div>	<div>Because facility design significantly affects security, it should be a priority in the planning for renovation of an existing unit or a new unit. Care should be taken to <b>limit the number of exits and entrances</b> to the unit.</div> <div>room: <i>entrance, reception</i></div> <div>measure: <i>spatial design</i></div>	
Preliminary Design		
<div>G.3</div> <div></div>	<div>Control station(s) should be located within close proximity and direct visibility of the entrance to the infant care area. The control point should be situated so that all visitors must walk past the station to enter the unit. The design should provide for maximum visibility of the nursery from the workroom or charting area.</div> <div>(Mahle &amp; Kinday, 2008) A view of a single private room and nurse station.</div>	
	<div>room: <i>entrance, reception</i></div> <div>measure: <i>spatial design</i></div>	
<div>G.4</div> <div></div>	<div>Security considerations should not adversely affect the quality of spaces for families in the NICU. The need for security should be <b>balanced</b> with the needs for comfort and privacy of families and their infants.</div> <div>A view of the nurse station surrounding private NICU rooms (Mahle &amp; Kinday, 2008)</div>	
	<div>room: <i>family rooms</i></div> <div>measure: <i>spatial design, interior design</i></div>	




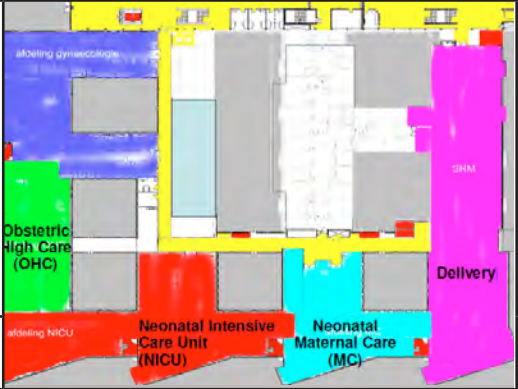




# H. Orientation, Routing, Logistics



3D view of Room Configuration NICU UZ Leuven (DJGA, 2009)



#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users
I.B.A	Reducing Walking Distances; Type of Unit Layout	Large walking distances increase the time for performing a tasks and decrease comfort and productivity at work (Bird et al., 2011)	all rooms	Staff
I.B.B	Reduce Walking Distances; decentralised nursing stations	Reducing the time to spend searching for supplies and gathering can help to reduce stress and nurses can then spend more time caring for patients	all rooms	Staff
II.G.A	Integrated Routes	routes that are, on average, more accessible because they are fewer turns from all other routes in the hospital.	all rooms	Staff, Family

Draft Design				
H.1 	The NICU shall be in close and controlled proximity to the area of the hospital where births occur. When obstetric and neonatal services must be on separate floors of the Hospital, an elevator located adjacent to the units with priority call and controlled access by keyed operation shall be provided for service between the birthing unit and the NICU. (Coull et al., 2011)			
	Rooms: <i>All rooms</i> Measure: <i>Spatial configuration</i>	NICU layout (Mohns, 2013)		
H.2 	The NICU shall have a clearly identified entrance and reception area for families. Families shall have immediate and direct contact with staff when they arrive at this entrance and reception area.			
	Rooms: <i>Entrance, Reception</i> Measure: <i>Spatial configuration</i>	NICU Entrance (Children's Hospital Colorado., 2015)		
H.3 	When possible, views of nature shall be provided in at least one space that is accessible to all families and one space that is accessible to all staff.			
	Rooms: <i>bedrooms, family rooms</i> Measure: <i>Spatial configuration</i>	Corridor NICU Zone (DJGA, 2013)		



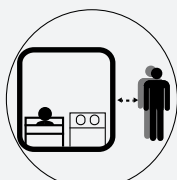


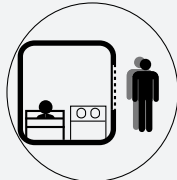



# I. Privacy, Autonomy



Privacy for Family Visiting the Infant (Ashford and St Peter's Hospitals, 2014)

#	Principles of Physical Space for Healing Environment (Ulrich et al., 2004)	Problem/issue	Room/Space (elements) (White, 2012)	Aimed users
II.I	Single-bed rooms	single-bed rooms for auditory and visual privacy (Barlas et al., 2001)		Patients
III.F.B	Space and Comfort	Single-rooms provide more space and furniture than double rooms to accommodate family presence (Chaudhury et al., 2003)		Patients, Family

Draft Design			
	<p>I.1</p> <p>the NICU should be a <b>distinct, controlled area</b> immediately adjacent to other perinatal services, except in those local situations (e.g., free-standing children's hospitals) where exceptions can be justified. Transport of infants within the hospital should be possible without using public corridors.</p> <p>Transport to Specialised Neonatal Facilities (Whyte, 2009)</p>		
	<p>room: <i>all rooms</i></p> <p>measure: <i>spatial configuration</i></p>		
	<p>I.2</p> <p>The need for privacy for infants and families should be addressed by <b>minimising traffic flow</b> past each bed.</p>		
	<p>room: <i>bedrooms, family rooms</i></p> <p>measure: <i>spatial configuration</i></p>		
Preliminary Design			
	<p>I.3</p> <p>Windows and doors shall be designed for <b>visual and acoustical privacy</b> and shall allow easy exchange of an infant between personnel.</p> <p>Privacy for Mother and Child in NICU Room (Rowley, 2010)</p>		
	<p>room: <i>bedrooms, family rooms</i></p> <p>measure: <i>interior design, building physics</i></p>		
	<p>Airborne infection isolation rooms shall have <b>observation windows</b> with internal blinds or switchable privacy (opaquing) glass for privacy.</p>		
	<p>room: <i>isolation rooms</i></p> <p>measure: <i>spatial design, building physics</i></p>		
Detail Design			
	<p>I.4</p> <p><b>Consultation Room:</b> This should include comfortable seating and allow complete visual and acoustic privacy.</p> <p>Lighting in NICU family support rooms (Smith Seckman Reid, 2015)</p>		
	<p>room: <i>consultation rooms</i></p> <p>measure: <i>interior design</i></p>		
	<p>These areas include <b>lockers, lounges, counseling, education and conference space</b>, and on-call rooms that provide privacy and satisfy their intended function.</p>		
	<p>room: <i>bedrooms, family rooms</i></p> <p>measure: <i>spatial configuration</i></p>		



# Discussion

When looking at the different spatial solutions for a NICU architectural design, three incongruities in particular can be found. These are discussed below:

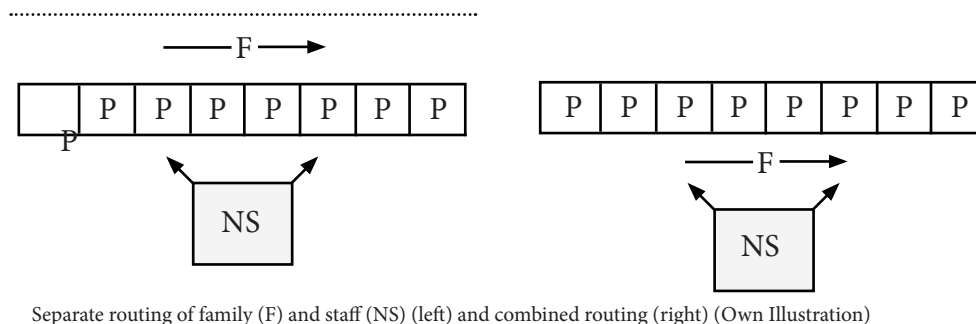
- **Acoustic comfort versus daylighting/safety:** There is a tradeoff between the use of opaque porous sound-absorbing material and glass for see-through for views outside or monitoring. Although the porous sound-absorbing material can be delivered in a sterile version, these materials (e.g. wall panels)

can suffer from damage by hospital use, and thus not being sterile anymore. Glass makes the room far more sterile, but has a negative effect on the room's acoustical experience. In the trade-off between daylighting/safety and acoustic comfort, the different rooms can be placed on a spectrum (see below).



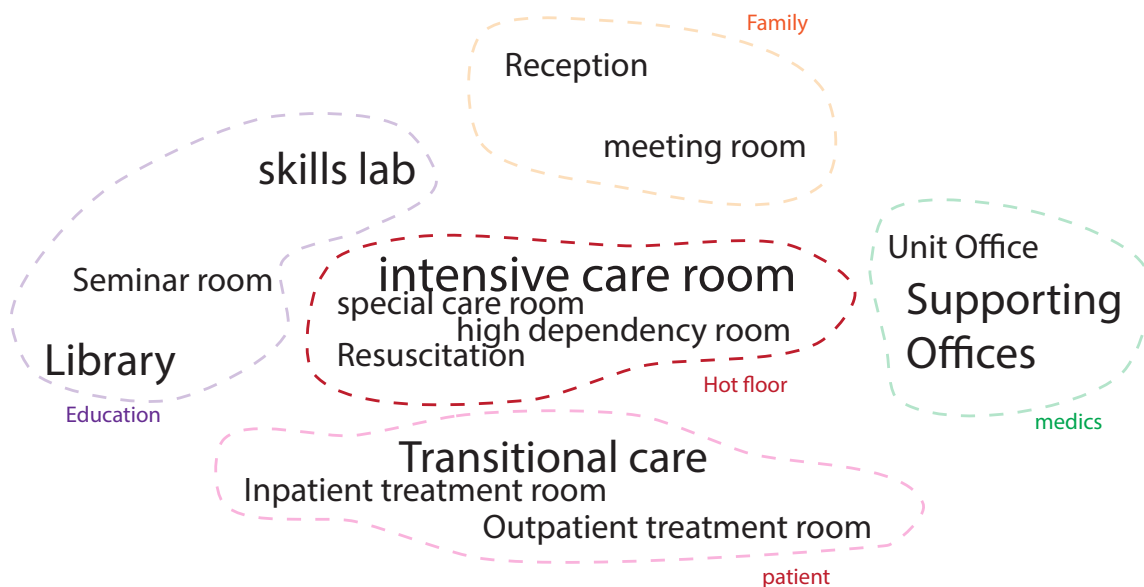
- **Routing and logistics versus privacy, safety and security:** for the benefit of good routing of the different users (i.e. patient, medical staff and family) through the NICU floor, different entrances and corridors are preferred. However, this conflicts with security

(visitors on floor less controllable; risk of child abduction), safety (e.g. airborne infection) and privacy (more doors and windows on the floor). There can be made a difference in separating the routing of family and medics. An example (left: separated, right: combined) is given below.



- **Temperature and air quality versus routing and logistics:** in sustaining a constant temperature and air quality in treatment rooms (i.e. operative, delivery and resuscitation rooms) the doors of the room should be shut as much as possible. However, since acute treatment is done in this room, doors

will open frequently for medical staff running in and out. Therefore, these rooms are positioned central in the building to optimise routing and logistics. Therefore, a subdivision between the 'hot floor' (i.e. IC, high dependency and special care room, resuscitation) and other functions is imperative.





# Conclusion

## SQ1

*“What technical and spatial objectives that serve a healing environment conflict in an architectural design for the NICU?”*

In designing the NICU facility, different themes relating to Healing Environment conflict with one another in spatial and architectural solutions. Some tradeoffs (e.g. acoustic comfort versus daylighting/safety) can be settled on level of room, e.g. it has to be chosen if these rooms are more lightened or they have opaque walls with acoustic wall panels instead. This choice influences the position of the room in the configuration of the NICU floor. This aligns with the position that follows from the grouping of rooms regarding the tradeoff ‘temperature and air quality versus routing and logistics’. Again, we consider a tradeoff on level of configuration of rooms (should it be placed centrally in the building - routing and logistics, accessibility) and on level of room (should it be closed with locks, impermeable - temperature and air quality). The last foremost conflict considers a tradeoff on level of configuration of rooms: The choice for an efficient routing and logistics can conflict with the configuration of windows and doors for privacy and security.



Healing Environment in Emma Children's Hospital  
(Visser & Smit Bouw, 2014)

# Chapter B

## Constraints for an Optimised NICU Architectural Layout



Room Configuration on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)

# Introduction

## SQ2

*“How are the subsequent technical and spatial **constraints** embodied in precedent designs for NICU?”*

This chapter intends to exhibit the constraints for principles of healing environment, to be found in precedent designs for NICU. Using the literature research, it is assessed how these Neonatal IC Units score on the different themes for the quality of the built environment (TNO, 2009).

On the next page, the four precedent designs will be introduced. Evidently, the difference in layouts are the result of different design choices, relating to what the architect (and thus the users) found important for the configuration of the NICU floor. Once again, this shows how strongly related the form of facilities and function of healthcare processes are.

Subsequently, the apprehension of themes for Quality of the Built Environment in the four distinct layouts will be highlighted separately. This will very specifically show how latent healthcare processes have influenced the design choices for e.g. acoustics, daylighting or routing.

In the discussion the three main conflicting themes, found in the literature study, will be highlighted again, to show what diversity in solutions is presented in the precedents. Finally, this chapter concludes by summarising how technical and spatial constraints are embodied in precedent designs for NICU.



Corridor NICU Zone (DJGA, 2013)

# Reference Projects

## NICU Wilhelmina Children Hospital UMC Utrecht



Entrance Wilhelmina Children's Hospital (WKZ, 2013)

Architect: EGM Architecten  
Completion: 1999  
Capacity: 20 incubators (high care)  
6 incubators (isolation)  
2 family beds

- Infant bedroom
- Mother bedroom
- Operative room
- Infection isolation room
- Charting/Staff
- Technical support
- Cleaning/storage
- MEP service room
- MEP service shaft
- medics support
- meeting room
- Family Support
- Family Entry/ Reception
- Family bedroom



Room Configuration on Technical Drawing Neonatology Department (2nd floor) Wilhelmina Children Hospital (EGM, 1997)

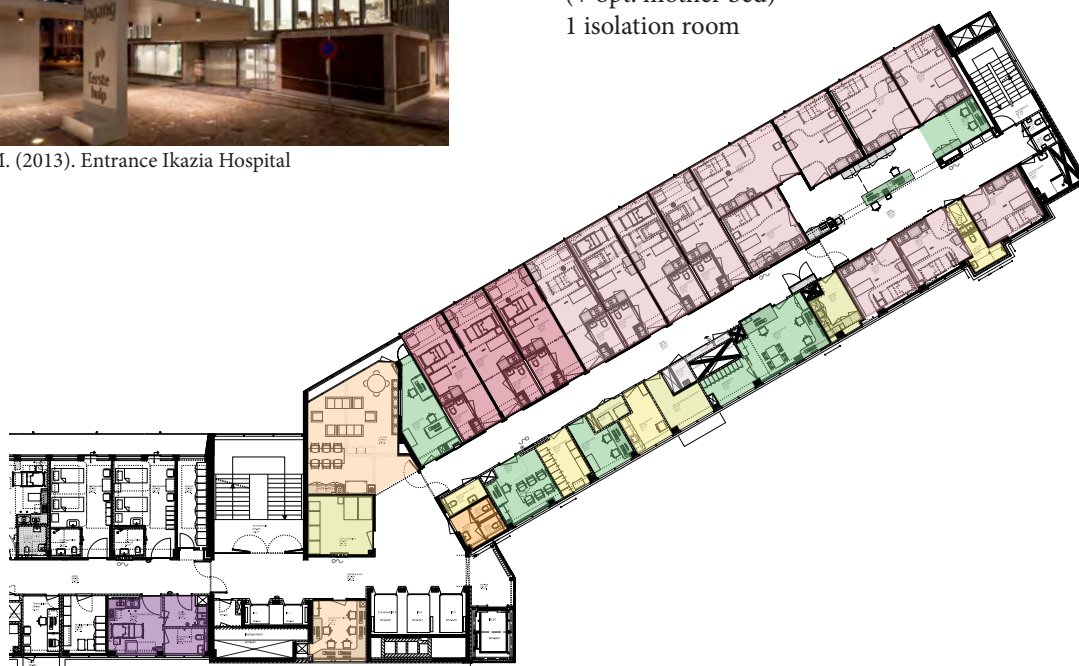
## NICU Ikazia Hospital Rotterdam



EGM. (2013). Entrance Ikazia Hospital

Architect: EGM Architecten  
Completion: 2010  
Capacity: 7 mother bed + incubator rooms  
8 incubator rooms  
(+ opt. mother bed)  
1 isolation room

- Infant+mother/ family bedroom
- Family suite
- Operative room
- Infection isolation room



Room Configuration on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)

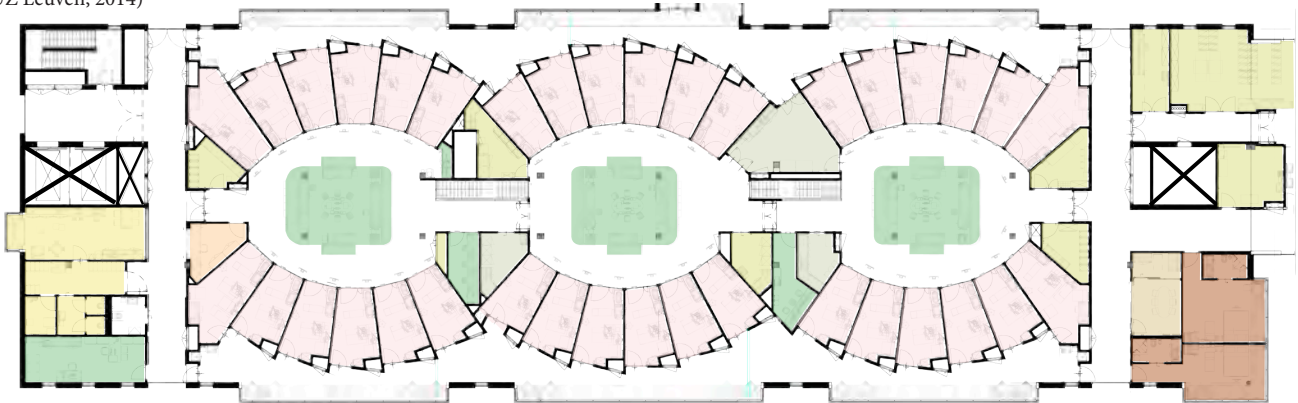


## NICU UZ leuven



Hospital Department Critical Services (including NICU)  
( UZ Leuven, 2014)

Architect: DJGA architecten  
Capacity: 36 incubators (high care)



Room Configuration on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)

## NICU Maxima Medisch Centrum Veldhoven



Hospital Mother-Child Centre (including NICU)  
( DJGA, 2014)

Architect: DJGA architecten  
Capacity: 22 incubators (high care)



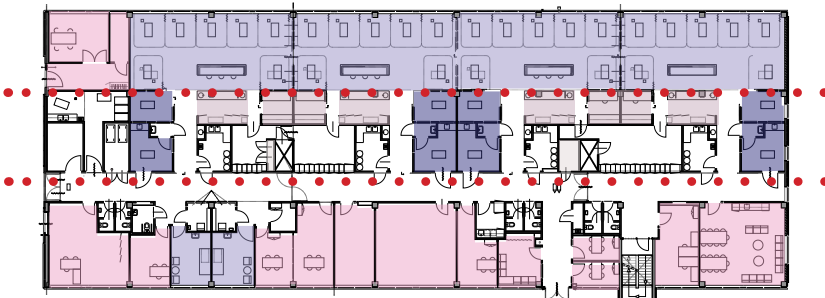
Room Configuration on (Cutout of) Technical Drawing Mother-Child Centre (2nd floor) MMC Veldhoven (DJGA, 2007)



# A. Acoustics

- highly silent room
- silent room
- conversation room
- treatment room

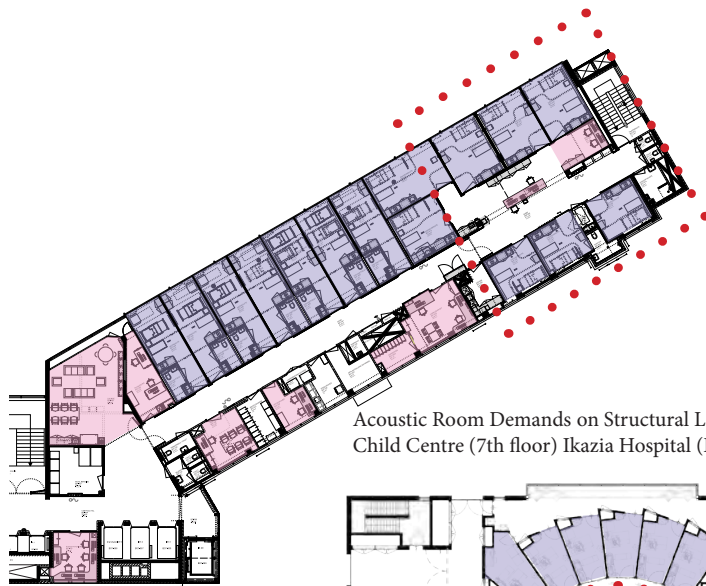
scale drawings 1:625



Acoustic Room Demands on Technical Drawing Neonatology Department (2nd floor)  
Wilhelmina Children Hospital (EGM, 1997)

## Buffer

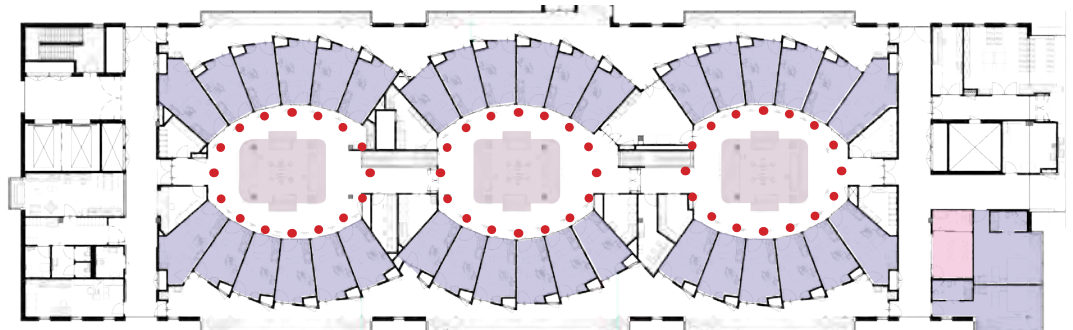
The NICU Floor layout is constrained to placing functions such as the charting/staff work areas close to the isolation rooms in the buffer. Therefore, a (loud) treatment room is placed next to a (highly silent) isolation room.



Acoustic Room Demands on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)

## end of wing

If the NICU floor is situated in a wing, incubator suites are placed at the end of the hallway (more silent)



Acoustic Room Demands on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)

## sound mitigation work area

In a panopticum layout type, acoustic interventions have to mitigate sound in the 'loud treatment areas' in the center of the NICU.

## clustered conversation rooms

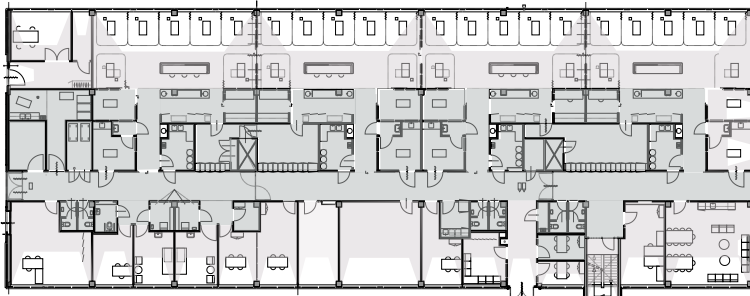
In case of more adjacent wings, conversation rooms should be situated next to one another in a single wing



Acoustic Room Demands on (Cutout of) Technical Drawing Mother-Child Centre (2nd floor)  
MMC Veldhoven (DJGA, 2007)



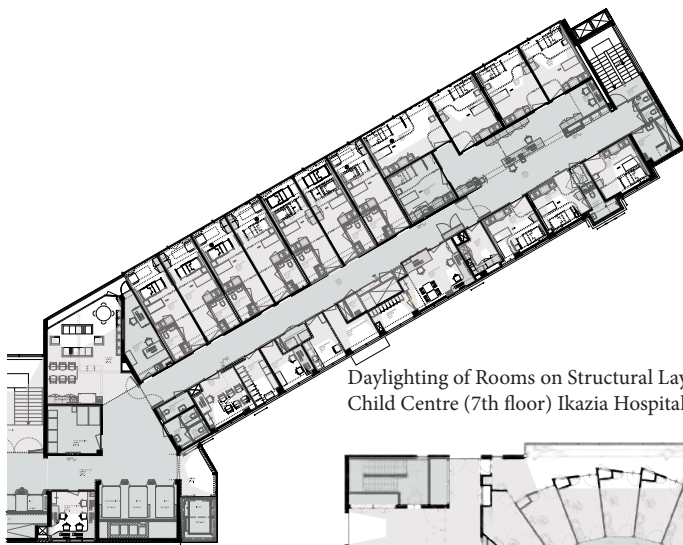
## B. (Day)lighting



Daylighting of Rooms on Technical Drawing Neonatology Department (2nd floor)  
Wilhelmina Children Hospital (EGM, 1997)

### Prioritisation

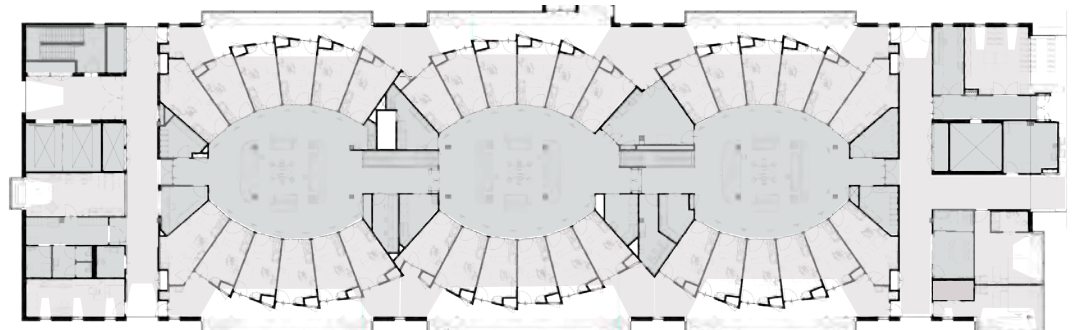
Patient rooms that need (only) little daylight are prioritised above staff work areas. Thus the medical staff has to respect to sit in the darker parts of the building.



Daylighting of Rooms on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)

### corridors or rooms lit

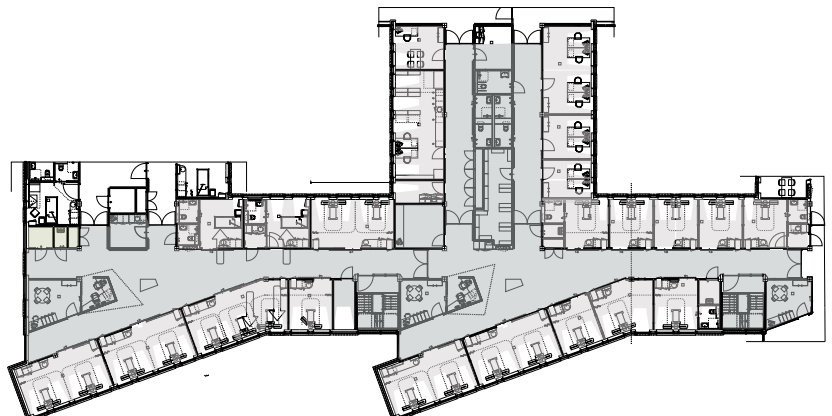
In a longitudinal building (wing) the choice has to be made for (lit) rooms on the outside, or for lit corridors.



Daylighting of Rooms on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)

### Rooflights/Artificial Daylight

In the panopticum layout type, daylight for staff and patients should be served in the central staff areas by means of rooflights/artificial daylight.



Daylighting of Rooms on (Cutout of) Technical Drawing Mother-Child Centre (2nd floor)  
MMC Veldhoven (DJGA, 2007)

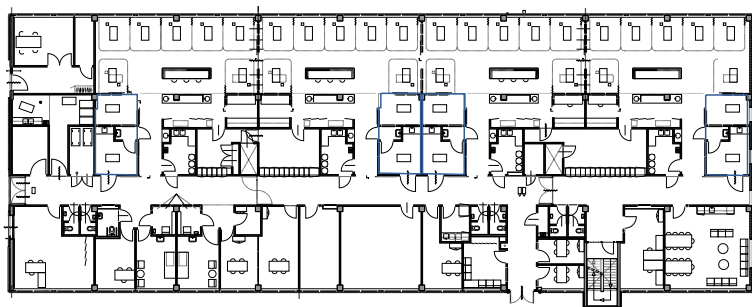




# C. Air Quality

 separate controlled air handling

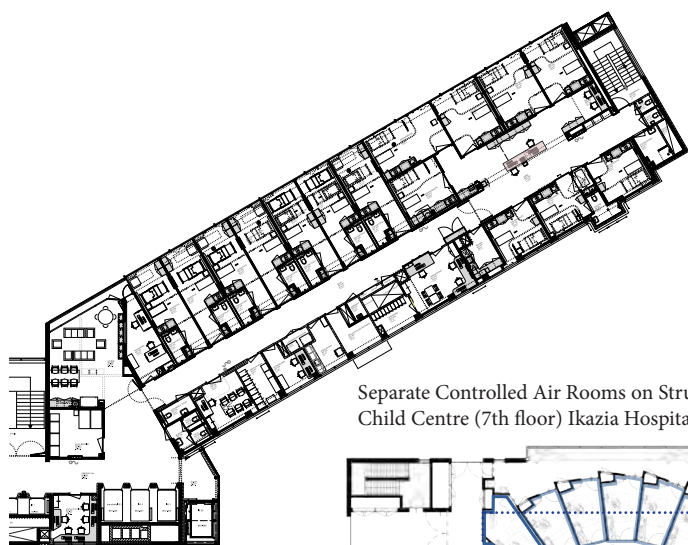
scale drawings 1:625



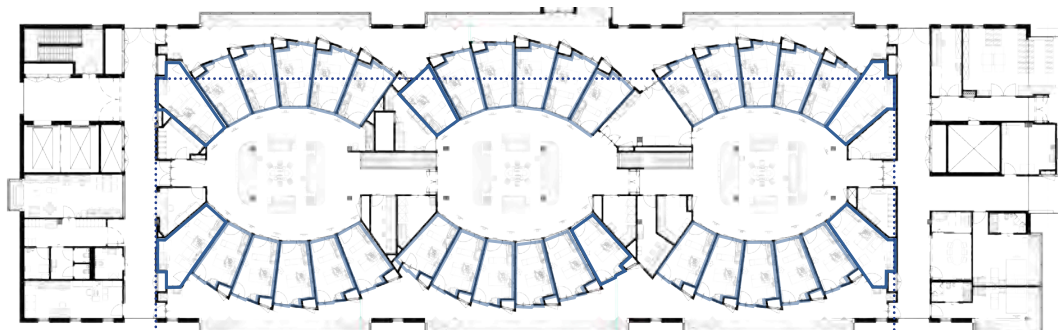
Separate Controlled Air Rooms on Technical Drawing Neonatology Department (2nd floor)  
Wilhelmina Children Hospital (EGM, 1997)

## Isolation Rooms

isolation rooms with controlled ambient air should be placed in the core of the floor. Rooms that allow for interference with other air currents (open a window) should be placed on the outside.



Separate Controlled Air Rooms on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)



Separate Controlled Air Rooms on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)

## Locked of

In case separated isolation rooms are opened up to a central corridor, the corridors should be locked of from the rest of the hospital (department) to prevent air current interference



Separate Controlled Air Rooms on (Cutout of) Technical Drawing Mother-Child Centre (2nd floor) MMC Veldhoven (DJGA, 2007)





## D. Temperature

normal temperature (18-20 °c)  
 controlled ambient temperature  
 22-26 °c), relative humidity 30-60%  
 scale drawings 1:625



Temperature of Rooms on Technical Drawing Neonatology Department (2nd floor)  
 Wilhelmina Children Hospital (EGM, 1997)

### Isolation Rooms

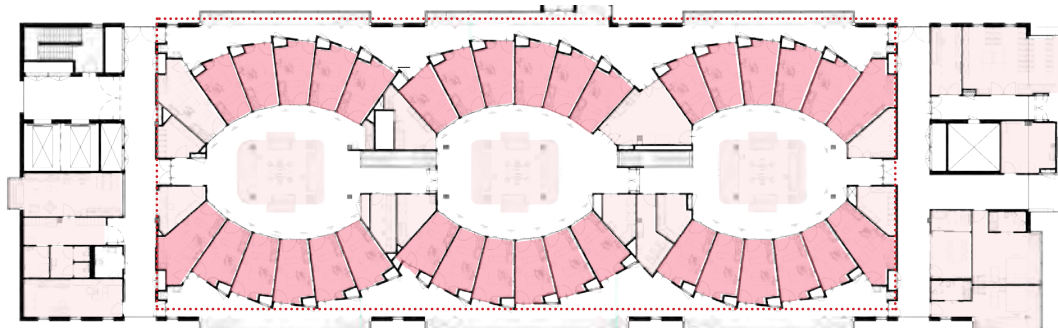
isolation rooms with controlled ambient temperature placed in the core of the floor to remain the heat inside the building.



Temperature of Rooms on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)

### Linking of Rooms

Rooms with controlled ambient temperature should be placed next to one another to reduce heat loss.



Temperature of Rooms on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)

### Isolation Zone

In case separated isolation rooms are opened up to a central corridor, the corridors should be locked off from the rest of the hospital (department) to prevent air current interference



Temperature of Rooms on (Cutout of) Technical Drawing Mother-Child Centre (2nd floor) MMC Veldhoven (DJGA, 2007)

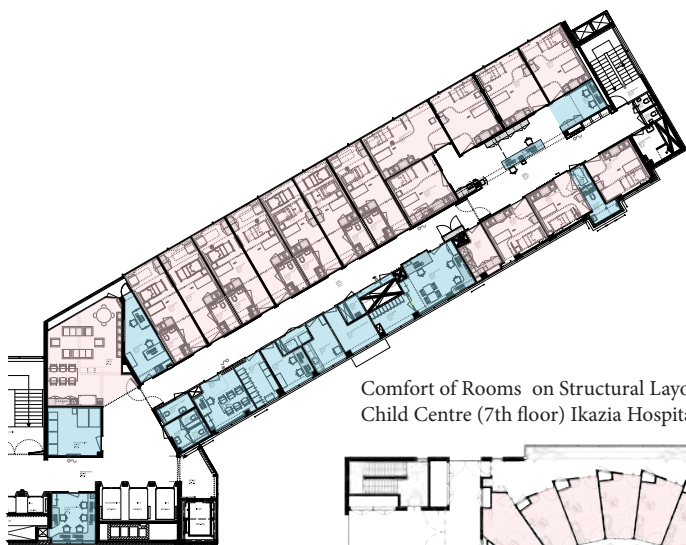


## E. Comfort, Sensoric Quality

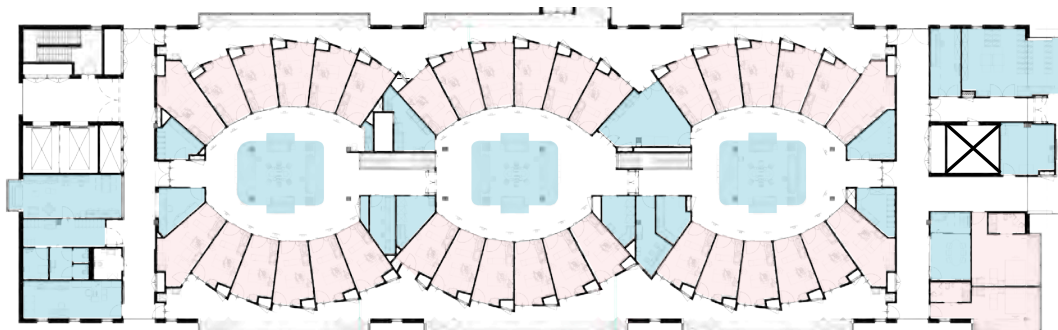
rooms for comfort  
rooms for utility  
scale drawings 1:625



Comfort of Rooms on Technical Drawing Neonatology Department (2nd floor)  
Wilhelmina Children Hospital (EGM, 1997)



Comfort of Rooms on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)



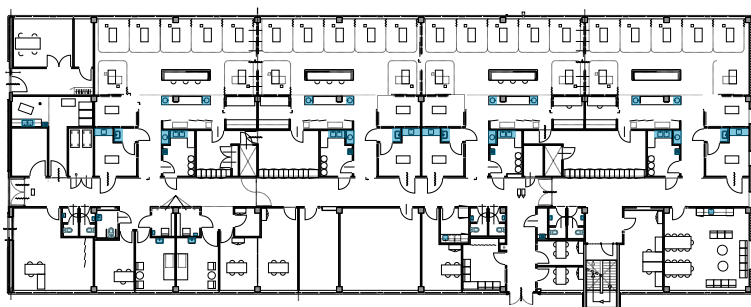
Comfort of Rooms on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)



Comfort of Rooms on (Cutout of) Technical Drawing Mother-Child Centre  
(2nd floor) MMC Veldhoven (DJGA, 2007)

### Separating functions

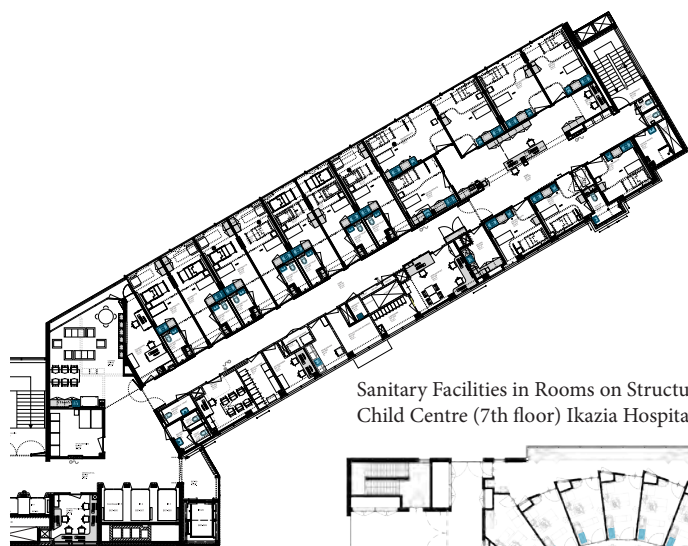
staff/charting work areas should be as much out of sight of the patient and family as possible. Patient rooms should feel like a 'home' in which the doctor visits, instead of a clinical room which the patient visits. Keeping these functions apart will add to this.



Sanitary Facilities in Rooms on Technical Drawing Neonatology Department (2nd floor)  
Wilhelmina Children Hospital (EGM, 1997)

## Shafts

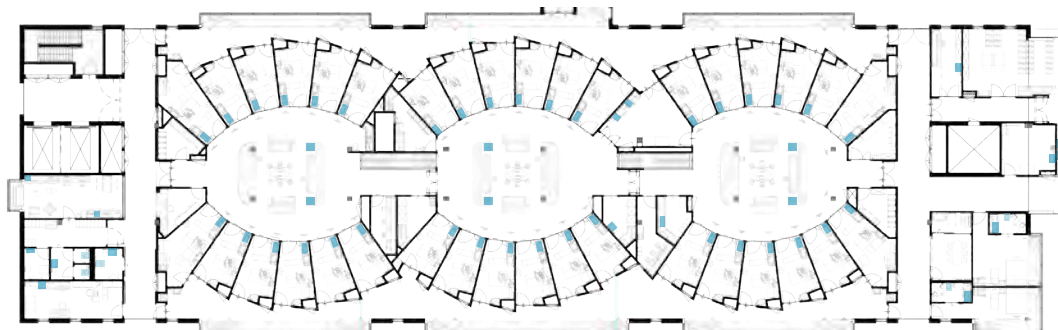
Handwashing sinks need to be placed centrally to make public sanitation shafts space efficient.



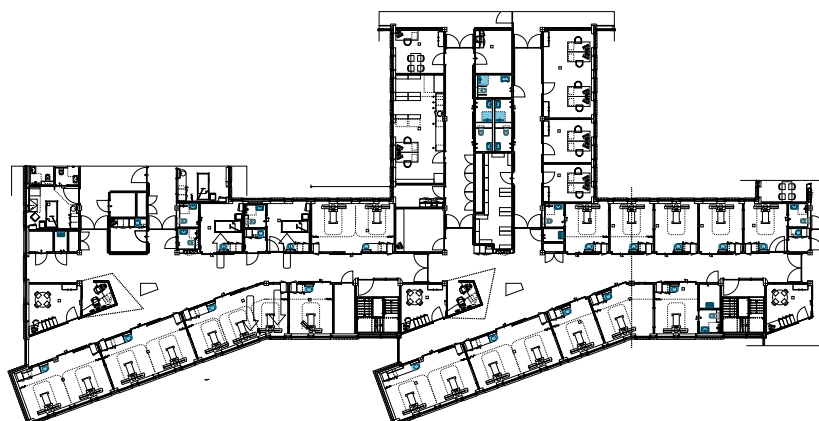
Sanitary Facilities in Rooms on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)

## Single Family Rooms

SFRs need a single toilet and washing sink per room



Sanitary Facilities in Rooms on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)

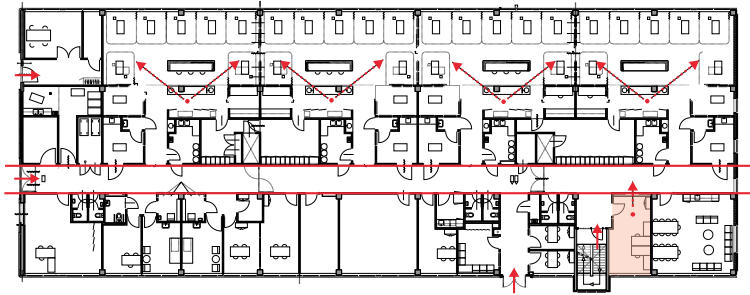


Sanitary Facilities in Rooms on (Cutout of) Technical Drawing Mother-Child Centre (2nd-floor) MMC Veldhoven (DJGA, 2007)



## G. Safety, Security

- entrance to NICU
  - visual control
  - main visible route
  - reception
- scale drawings 1:625



Monitorability of Rooms on Technical Drawing Neonatology Department (2nd floor)  
Wilhelmina Children Hospital (EGM, 1997)

### Reception

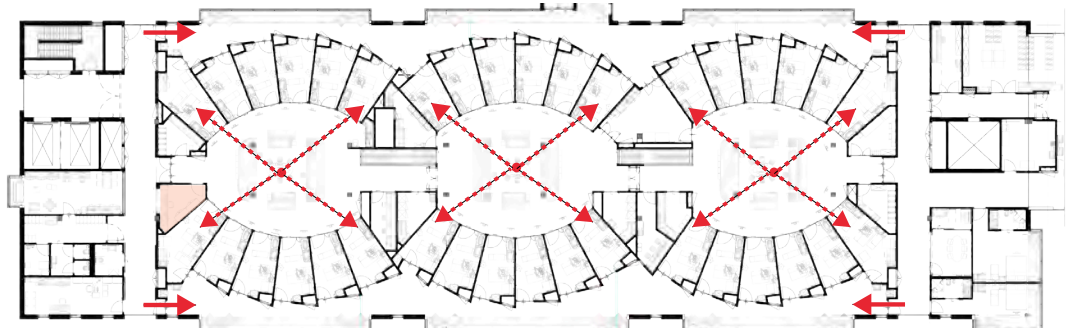
The reception should be placed central in the NICU configuration, to have maximum overview over visitors.



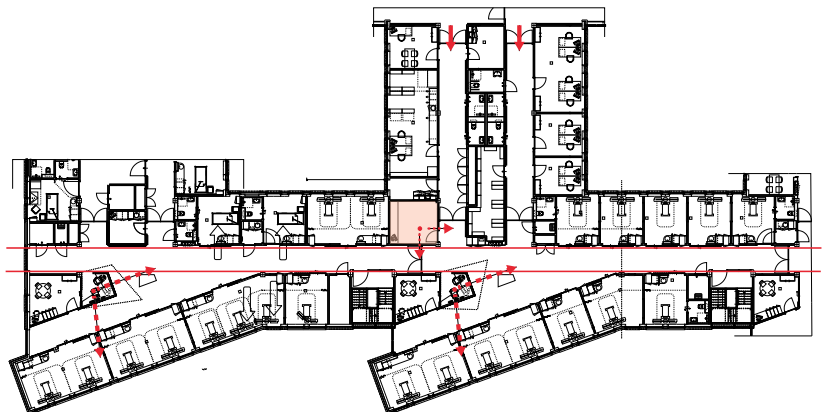
Monitorability of Rooms on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)

### Number of Entrances

The number of entrances should be as less possible to guarantee a good overview.

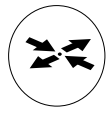


Monitorability of Rooms on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)



Monitorability of Rooms on (Cutout of) Technical Drawing Mother-Child Centre (2nd floor) MMC Veldhoven (DJGA, 2007)





# H. Orientation, Routing, Logistics

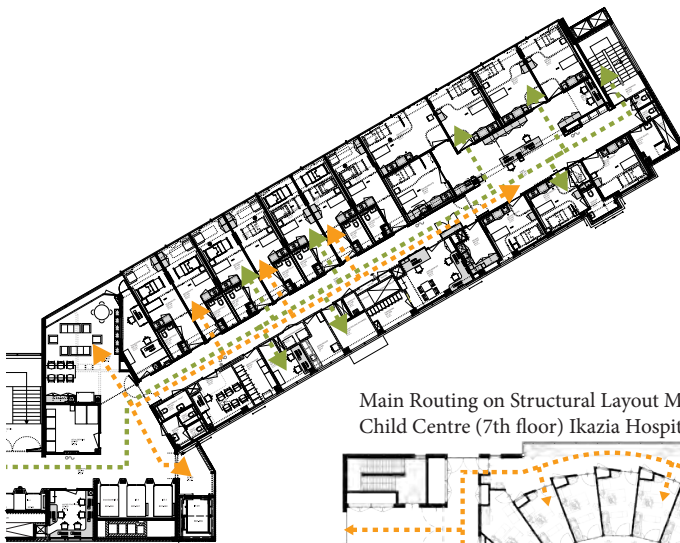
- medics main routes
- family main routes
- scale drawings 1:625



Main Routing on Technical Drawing Neonatology Department (2nd floor)  
Wilhelmina Children Hospital (EGM, 1997)

## Direction

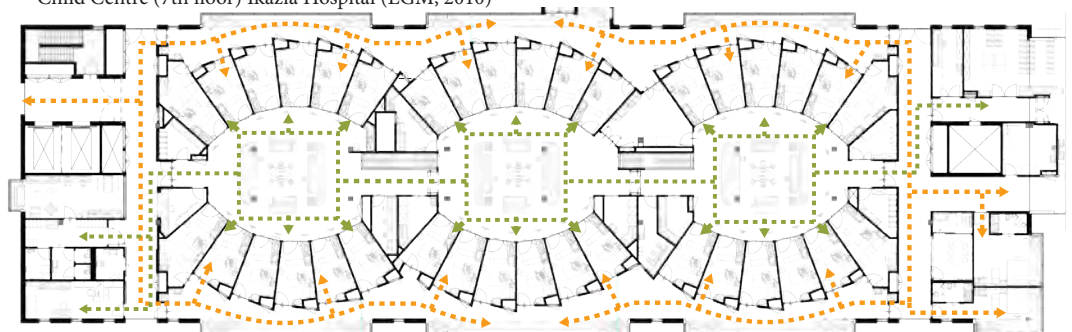
routes of medics and family should be aligned and not perpendicular, to avoid interference with health care process



Main Routing on Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)

## One entrance

The family should enter the NICU floor only from one side, to keep overview and to avoid interference with health care process





Main Routing on Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)

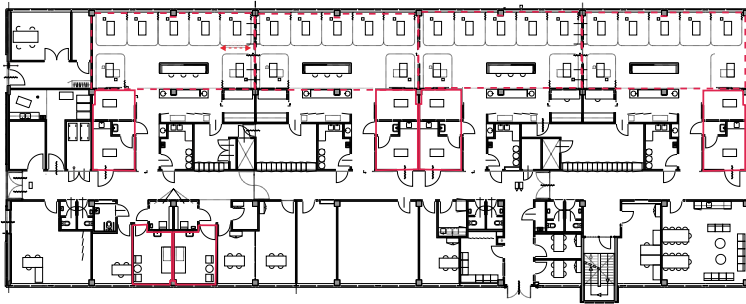


Main Routing on (Cutout of) Technical Drawing Mother-Child Centre  
(2nd floor) MMC Veldhoven (DJGA, 2007)

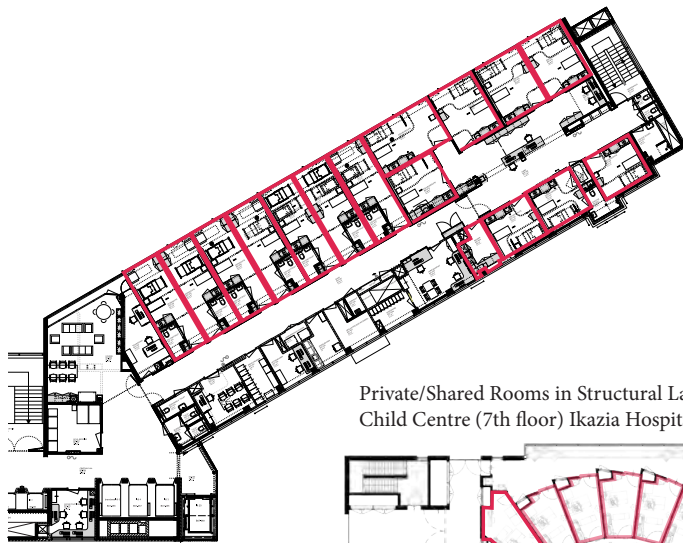


# I. Privacy, Autonomy

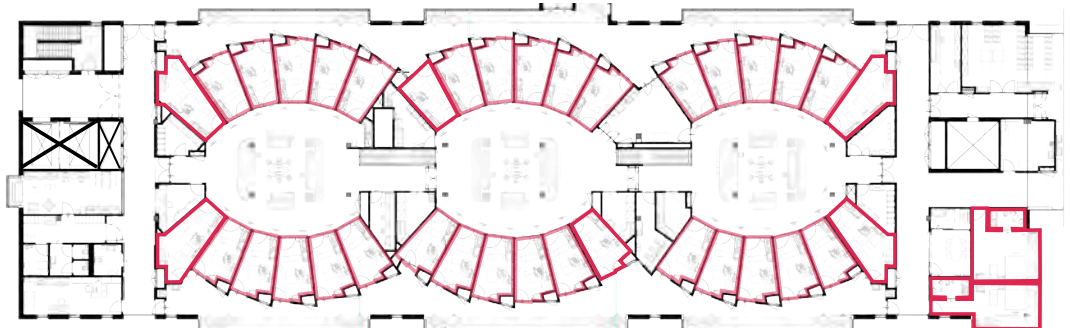
 private bed/incubator room:  
 shared bed/incubator room  
 scale drawings 1:625



Private/Shared Rooms in Technical Drawing Neonatology Department (2nd floor)  
Wilhelmina Children Hospital (EGM, 1997)



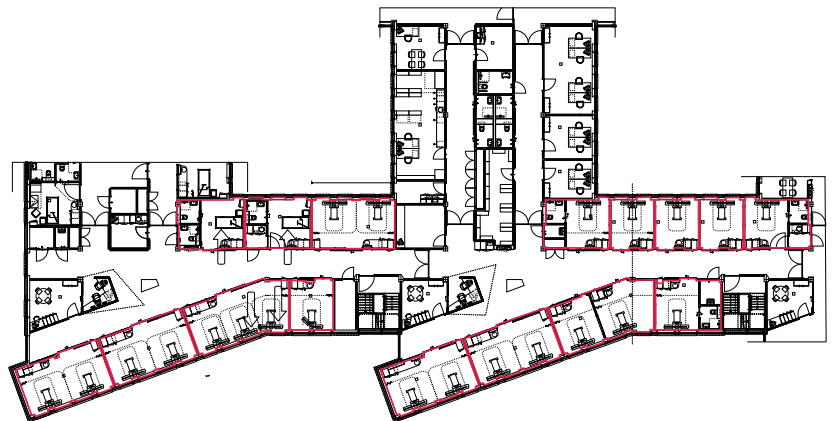
Private/Shared Rooms in Structural Layout Mother-Child Centre (7th floor) Ikazia Hospital (EGM, 2010)



Private/Shared Rooms in Technical Drawing NICU (3d floor) UZ Leuven (DJGA, 2009)

## Locks

In the UZ Leuven the patient zone is locked off with a door which can only be unlocked by a key by family and staff. Therefore, there is less traffic alongside the room, improving privacy.



Private/Shared Rooms in Technical Drawing Mother-Child Centre (2nd floor) MMC Veldhoven (DJGA, 2007)

## Privacy

Privacy comfort for family and patient can be acclaimed when the routing alongside the room and the open views into the bed-rooms are kept to a minimum. If the room is directly adjacent to the central corridor, interior panels can be used to create more private spaces.

# Discussion

## - Acoustic comfort versus daylighting/safety:

From the different layouts it comes forward that there are different ways to structure the acoustic comfort versus daylighting/safety issue:

In the UMC Utrecht there is a clear zoning between the incubator rooms (silent), the isolation rooms and medic rooms (mixed), and the corridor and family (support) rooms (loud). In case of the Ikazia hospital, such zoning is achieved more implicitly, by placing the incubators at the end of the wing. In the UZ Leuven the patient rooms (clustered around central bays (nurse stations) are separated from offices and meeting rooms.

In the division between rooms that request daylighting over acoustics, it can be seen that the UMC Utrecht makes this clear distinction (e.g. by placing the airborne-isolation rooms in the core of the building). However, the four incubator rooms are placed in daylighted areas. It can be suggested that it would be better to situate the medical staff rooms on the outside instead. For the Ikazia hospital, the NICU floor is situated in a very slender building wing. Therefore, a distinction between rooms along the central corridor cannot be seen. Acoustic measures are introduced in other ways (i.e. building physics). In the design for the UZ Leuven, acoustics wins over daylighting: due to the panopticum layout type, the patient rooms are not directly lit by external windows and in the central bay acoustic ceiling elements are chosen over rooflights.

## - Routing and logistics versus privacy, safety and security:

Again, different NICU floors have different routes for the different groups through the layout:

Both in the UMC Utrecht and the Ikazia hospital there is a central corridor which is used by both the family and medical staff. Whereas the incubators in case of the UMC are situated equally divided over the whole floor (resulting in family traffic on all sides of the floor), in Ikazia a better division is made between the openly accessible family rooms at the top of the wing, and the less accessible incubator rooms at the end of the wing. For the UZ Leuven, the panopticum layout type implies that the corridors are placed on the outside, resulting in routing on the outside. Moreover, the main routes of staff and family are separated. This results in less conflicting traffic. In MMC Veldhoven the nursing stations are placed central, on the junctions between corridors, thus also providing with overview of the rooms on these corridors.

In the Ikazia hospital, the reception is not placed at the entrance or at the junctions of corridors, thus more difficult to recognise. The receptions of the UMC and MMC are placed at the junction of corridors, thus being better recognisable and giving more overview over the floor. Lastly, in the UZ Leuven the reception is placed at the entrance at one side of the patient zone.

## - Temperature and air quality versus routing and logistics:

In all NICU floors it is visible that the rooms necessitating for a controlled ambient temperature for the infant are situated together. This has the mere advantage that these rooms can be closed off from the other rooms with locks (to make them airborne-infection and temperature isolated). However, these locks have not been placed in case of the UMC Utrecht and Ikazia hospital floor. In case of the UZ Leuven the total patient zone is locked off from the rest of the hospital. However, there is not a distinct isolation room with locks. In MMC Veldhoven the isolation rooms are placed close together. Here, the rooms have a two-door lock system as a buffer.

The panopticum layout of the UZ Leuven provides with efficiency for routing and logistics for treatments, but also gives room for direct airborne infection through the central bay.

# Conclusion

## SQ2

*“How are the subsequent technical and spatial **constraints** embodied in precedent designs for NICU?”*

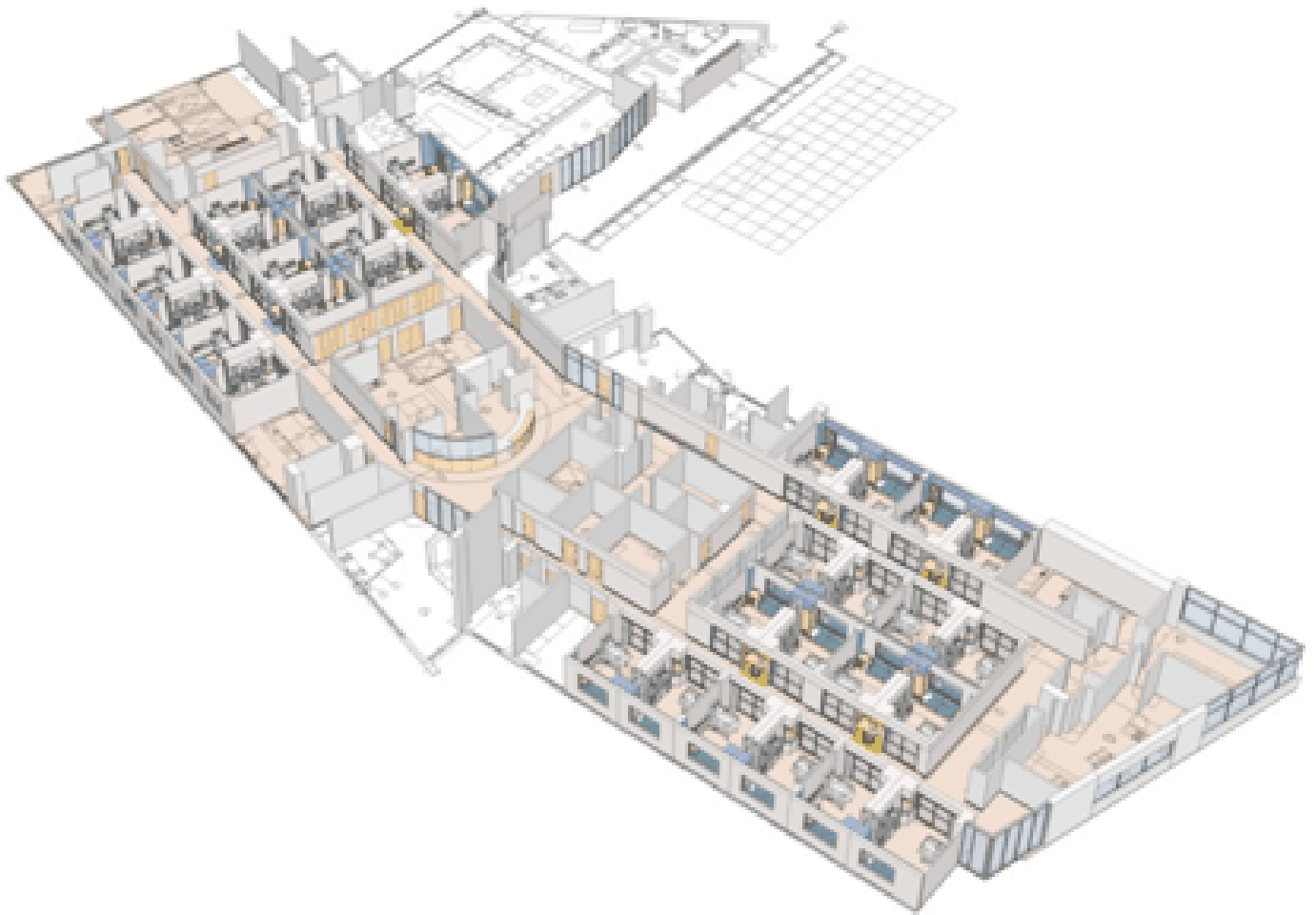
For resolving the acoustic comfort versus daylighting/safety issue, a careful trade-off should be made between placing the patient rooms on the outside of the floor (providing daylight for the patient) or placing the corridor on the outside (providing daylight for family/visitors). In case of an infant patient room, acoustics are also of major importance; thus it can be suggested that the choice should be made to place the corridors on the outside.

For routing and logistics versus privacy, safety and security it can be suggested to separate the traffic flows of medical staff and family. This provides with more room for both, and provides with more privacy. Reception areas should be placed at the entrance of the patient zone or at the junction of corridors.

Lastly, in serving a solution for the issue of temperature and air quality versus routing and logistics it is imperative that rooms with special needs (e.g. airborne-infection prevention) are clustered together, and this zone is locked off from the rest of the NICU. Next to this, a two-door lock for each room would furthermore reduce the infection danger.

# Chapter C

## Directives for a NICU Design



NICU Layout Providence, Rhode Island (Care New England, 2011)



# Introduction

SQ3

*“How can consequently technical and spatial objectives and constraints be translated into **directives** for a NICU Design?”*

In this chapter the findings from previous chapters (i.e. objectives (ch. A) and constraints (ch. B)) are aggregated and using the researcher’s own interpretation, it is demonstrated how these findings can be translated into directives.





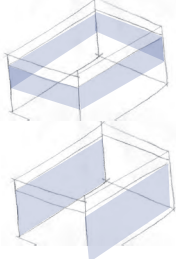

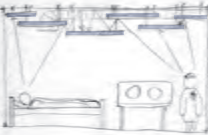


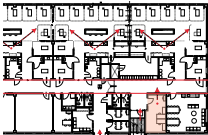

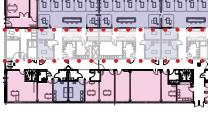
It is chosen to highlight the three foremost conflicts between Themes of the Quality of the Built Environment, to show how (means, i.e. spatial or building physics solution) and where (location, i.e. configuration in the NICU floor) the Principles of Healing Environment can be apprehended. First, a summary of the aims (ch. A) and the constraints (ch. B) are given, to further clarify the researcher’s arguments for the presented directives. The directives are presented in a spectrum of introduced design options, for the architect to chose from, depending on the nuances of the design requirement. Likewise, the layouts of existing NICU floors are placed amongst the introduced design options for reference.

In the discussion the design options are

to be added






# Acoustic comfort versus daylighting/safety

## Overview

Aims	Constraints
 <p>A.1 locate louder rooms, such as <b>Operative rooms</b>, away from patient rooms.</p>	<p><b>Buffer</b> - The NICU Floor layout is constrained to placing functions such as the charting/staff work areas close to the isolation rooms in the buffer. Therefore, a (loud) treatment room is placed to a (highly silent) isolation room.</p> <p><b>end of wing</b> - If the NICU floor is situated in a wing, incubator suites are placed at the end of the hallway (more silent)</p>
 <p>B.5 In locations where functions overlap with infant care areas (e.g., close proximity of the staff charting area to infant beds), the design should nevertheless permit <b>separate light sources</b> with independent controls so the very different needs of sleeping infants and working staff can be accommodated to the greatest possible extent.</p>	<p><b>Prioritisation</b> - Patient rooms that need (only) little daylight are prioritised above staff work areas. Thus the medical staff has to respect to sit in the darker parts of the building.</p> <p><b>corridors or rooms lit</b> - The choice has to be made for (lit) rooms on the outside, or for lit corridors.</p>
  <p>F.2 Because facility design significantly affects security, it should be a priority in the planning for renovation of an existing unit or a new unit. Care should be taken to limit the <b>number of exits and entrances</b> to the unit.</p> <p>F.4 Security considerations should not adversely affect the quality of spaces for families in the NICU. The need for security should be <b>balanced</b> with the needs for comfort and privacy of families and their infants.</p>	<p><b>Reception</b> - The reception should be placed central in the NICU configuration, to have maximum overview over visitors.</p> <p><b>Number of Entrances</b> - The number of entrances should be as less possible to guarantee a good overview.</p>
Directives	
 <p>Use sound-absorptive wall surfaces on all walls in places where no sunlight is needed, or bigger surfaces on two opposite walls in rooms where sunlight is needed.</p> <p>rooms: IC procedure room, IC (high care), resuscitation room.</p>	 <p>Use acoustic absorbent wall panels or interior elements in rooms with glass walls and clinical interior.</p> <p>Rooms: high care and medium care bedrooms, seminar room, meeting room, skills lab, library</p>
 <p>Use acoustic absorbent ceiling tiles in places with glass walls and clinical interior where overview is imperative.</p> <p>Rooms: high care and medium care bedrooms, nurse stations</p>	 <p>Use acoustic absorbent interior elements in corridors with glass walls and clinical interior where overview is imperative.</p> <p>Rooms: corridor</p>
 <p>Place the mother's bed close to the window for outside view; the infant's incubator placed in a darker place that has more acoustic-absorbent surfaces</p> <p>Rooms: Single-Family Room</p>	 <p>Reception should be placed central in the NICU configuration; near to the entrance and/or on the junction of corridors</p> <p>Rooms: reception, entrance area</p>
 <p>Position loud areas such as the operative rooms, seminar room, meeting rooms and skills lab away from the patient rooms and nursing stations.</p> <p>Rooms: operative, seminar and meeting room, skills lab</p>	 <p>isolation rooms and other rooms that do not need daylight should be used as a buffer between the corridor and the IC rooms.</p> <p>Rooms: isolation rooms</p>

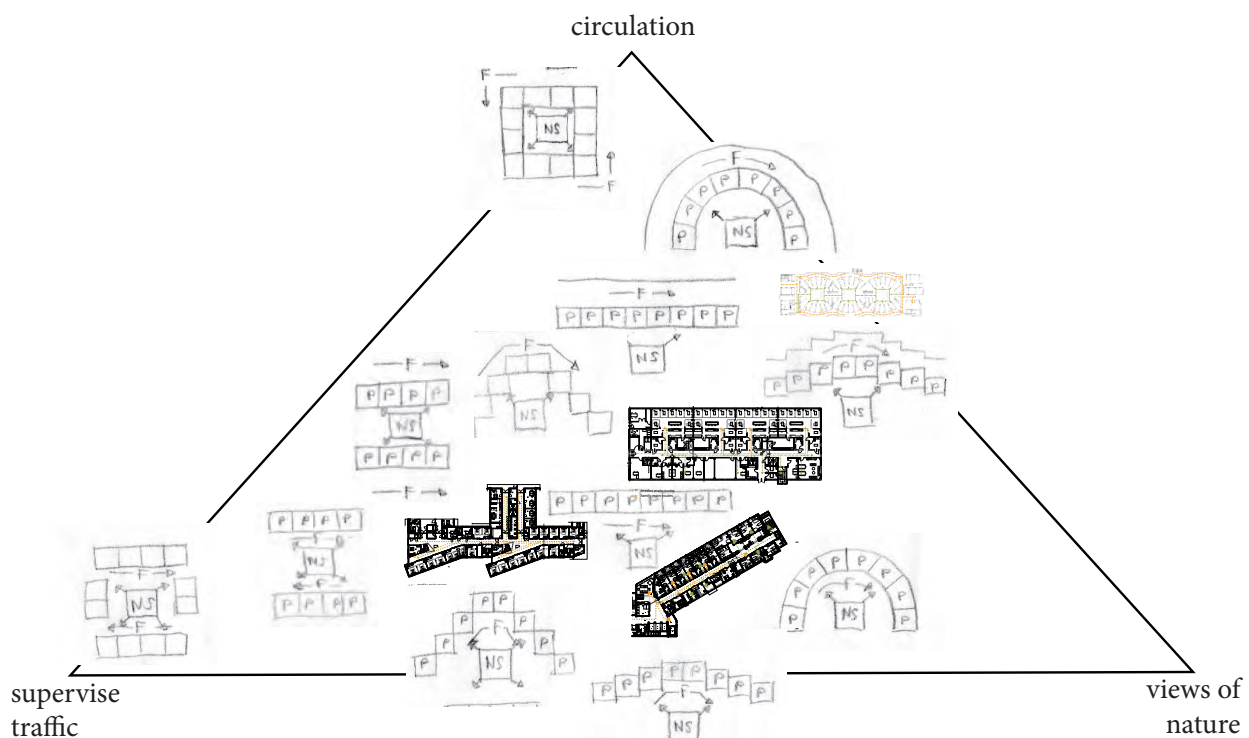
# Routing and logistics versus privacy, safety and security

## Overview

Aims	Constraints
 G.1 The NICU shall be designed as part of an <b>overall security program</b> to protect the physical safety of infants, families and staff in the NICU. The NICU shall be designed to minimise the risk of infant abduction.  G.4 Security considerations should not adversely affect the quality of spaces for families in the NICU. The need for security should be balanced with the needs for comfort and privacy of families and their infants.	<b>Reception</b> - The reception should be placed central in the NICU configuration, to have maximum overview over visitors. <b>Number of Entrances</b> - The number of entrances should be as less possible to guarantee a good overview.
 H.4 A clerical area should be located near the entrance to the NICU so personnel can <b>supervise traffic</b> into the unit. In addition, there should be one or more staff work areas, each serving 8 to 16 beds. These areas will allow groups of 3-6 caregivers to congregate immediately adjacent to the infant care area for report, collaboration, and socialization without impinging on infant or family privacy. When possible, <b>views of nature</b> shall be provided in at least one space that is accessible to all families and one space that is accessible to all staff.	<b>Direction</b> - routes of medics and family should be aligned and not perpendicular, to avoid interference with health care process <b>One entrance</b> - The family should enter the NICU floor only from one side, to keep overview and to avoid interference with health care process
 I.2 The need for privacy for infants and families should be addressed by minimizing traffic flow past each bed.  I.5 Windows and doors shall be designed for visual and acoustical privacy and shall allow easy exchange of an infant between personnel.	

## Directives

- The NICU shall provide effective **circulation** of staff, family, and equipment without congestion.
- A clerical area should be located near the entrance to the NICU so personnel can **supervise traffic** into the unit. In addition, there should be one or more staff work areas, each serving 8 to 16 beds. These areas will allow groups of 3-6 caregivers to congregate immediately adjacent to the infant care area for report, collaboration, and socialization without impinging on infant or family privacy.
- When possible, **views of nature** shall be provided in at least one space that is accessible to all families and one space that is accessible to all staff.

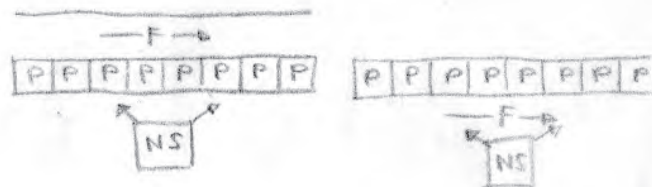


spectrum of design options (Own illustration)

# Routing and logistics versus privacy, safety and security Directives

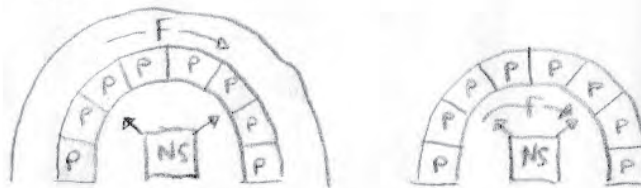
The configurations below can be used as an example for designing a NICU, on basis of considerations between circulation, supervising traffic and views of nature:

circulation: +  
supervise traffic: -  
views of nature: o



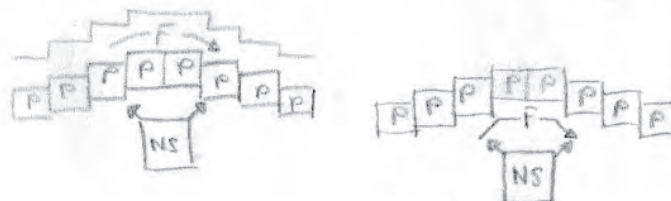
circulation: -  
supervise traffic: +  
views of nature: o

circulation: ++  
supervise traffic: -  
views of nature: +



circulation: --  
supervise traffic: +  
views of nature: +

circulation: +  
supervise traffic: -  
views of nature: +



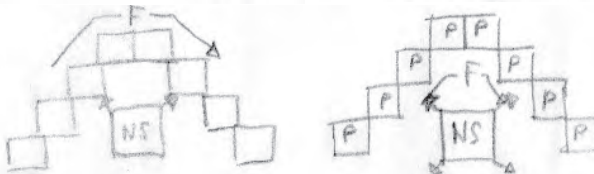
circulation: -  
supervise traffic: +  
views of nature: +

circulation: ++  
supervise traffic: o  
views of nature: --



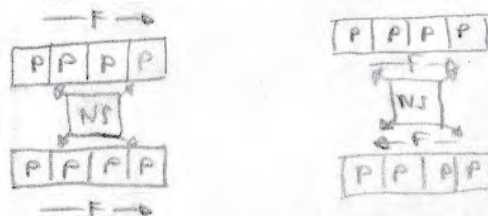
circulation: -  
supervise traffic: +  
views of nature: --

circulation: o  
supervise traffic: -  
views of nature: -



circulation: -  
supervise traffic: +  
views of nature: o

circulation: -  
supervise traffic: +  
views of nature: -







circulation: -  
supervise traffic: ++  
views of nature: o

Separate routing of family (F) and staff (NS) (left) and combined routing (right)  
(Own Illustration)



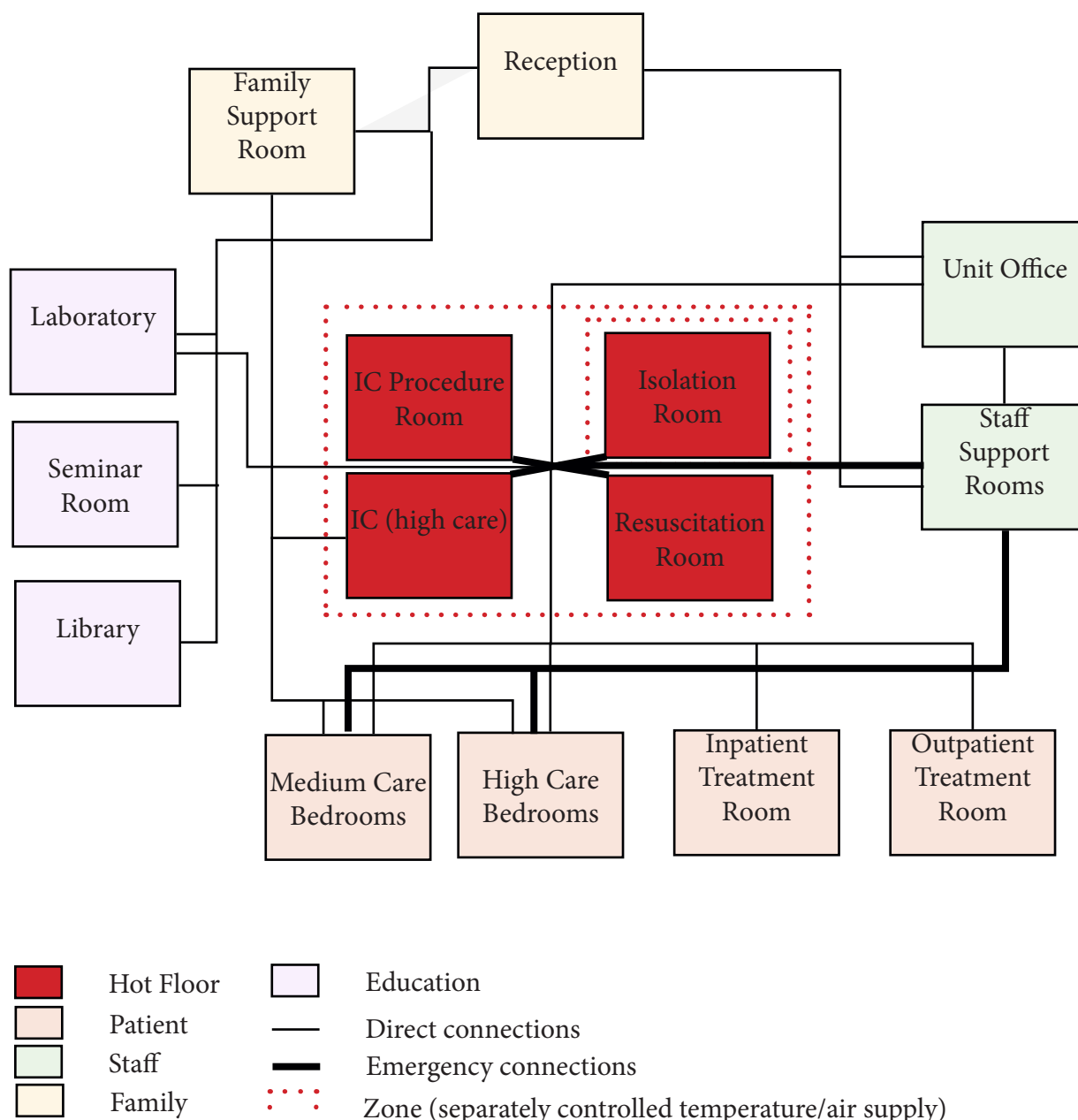
# Temperature and air quality versus routing and logistics

## Overview

Aims	Constraints
 C.2 A space within the NICU should also be available to safely cohort a group of infants infected with or exposed to a <b>common airborne pathogen</b> .  C.3 Airborne infection isolation room perimeter walls, ceilings and floors, including penetrations shall be sealed tightly so that <b>air does not infiltrate</b> the environment from the outside or from other airspaces.	<b>Isolation Rooms</b> - isolation rooms with controlled ambient temperature placed in the core of the floor  <b>Linking of Rooms</b> - Rooms with controlled ambient temperature should be placed next to one another to reduce heat loss.
 D.1 It is essential that the <b>appropriate ambient temperatures</b> can be achieved within a short time frame, since many high-risk deliveries occur with little warning.	
 H.2 The NICU shall have a clearly identified entrance and reception area for families. Families shall have <b>immediate and direct contact</b> with staff when they arrive at this entrance and reception area.	<b>Direction</b> - routes of medics and family should be aligned and not perpendicular, to avoid interference with health care process <b>One entrance</b> - The family should enter the NICU floor only from one side, to keep overview and to avoid interference with health care process

## Options Spectrum

Relation scheme between NICU rooms (Own Illustration)



# Discussion

The directives presented in this chapter show a spectrum of design possibilities that can be apprehended in order to convey healing environment in a NICU.

First, for the issue of acoustic comfort versus daylight/safety there are various ways to comfort the distinct rooms of a NICU. In the first place, acoustic comfort is decided by the configuration of rooms: e.g. by placing (loud) operative rooms away from (silent) patient rooms acoustic comfort can be improved. However, this is not possible in all cases, because of the limited space, and other requirements (e.g. routing) that have to be convened. As such, solutions in building physics can be opportuned: by using acoustic wall panels, ceiling tiles, flooring or interior elements nuisance can be attenuated.

The issue of routing and logistics versus privacy, safety and security regards different configurations of patient rooms and nursing stations, which allows for distinct routing of staff and family. The triangular spectrum presented how distinct configurations can be chosen on basis of considerations between circulation, supervising traffic and views of nature. These considerations can be seen as a trade-off between efficiency, safety/security and healing environment. The optimal configuration does not exist; it comes to the situation which configuration fits best.

Thirdly, the issue of temperature and air quality versus routing and logistics can be resolved by introducing different zones that have a separately controlled temperature and air supply. Preferably, these zones are locked off by a two-door lock.

# Conclusion

SQ3

*“How can consequently technical and spatial objectives and constraints be translated into **directives** for a NICU Design?”*

Technical and spatial directives for a NICU design on basis of Healing Environment can be derived from the objectives (set out in Healing Environment literature) and constraints (presented by precedents). From this, a spectrum of design options can direct the architect in finding an architectural solution.

Issues of objectives that conflict (i.e. acoustic comfort versus daylight/safety, routing and logistics versus privacy, safety and security, temperature and air quality versus routing and logistics) can be ordered on a scale which presents what spatial or technical solution fits best for the particular room, configuration of rooms or zones.

# Chapter D

## Example Programme of Requirements



Dyson Centre for Neonatal Care, Bath (Craig Aukland / Fotohaus, 2011)

# Example Programme of Requirements: AMC/VUMC

This chapter shows how a Programme of Requirements is composed, using the directives from this research paper. This example shows how particular aspects of Healing Environment can be incorporated. In this case the choice is made to highlight the consideration between acoustic comfort versus (day)lighting, and routing and logistics versus privacy.

## Introduction

In Amsterdam, the two academic hospitals, VU Medisch Centrum (VUmc) and the Academisch Medisch Centrum (AMC) admit to the current changes going on in health care, and see alliancing by means of merging both facilities on one location as their ambition (on the long-term) (Grift & Velden, 2013). One of the facilities that is anticipated to merge is the NICU. The design objective chosen concerns a new accommodation for the NICU positioned on location of the AMC hospital (Grift & Velden, 2013). This intensive care unit provides in a complete concentration of newborns and mothers within the intensive care, high care and medium care (Grift & Velden, 2013). The centre will be partly build as a retrofit within the existing structure and partly build as an expansion on the existing building structure (Valk, 2015). The design objective concerns the design of the complete delivery of the NICU.

## Directives

criteria passive building (Kuzman et al., 2013)		Acoustic comfort versus daylighting/safety	Routing and logistics versus privacy, safety and security	Temperature and air quality versus routing and logistics
	variant goal focus	solve acoustic solutions in a passive way notwithstanding optimal daylighting.	efficient routing and logistics notwithstanding private and safe healing rooms	sustaining in-room temperature and air quality notwithstanding the accessibility and openness for routine
	architectural focus	building shell	room configuration	room design
	aims	A.1, B.5, F.2, F.4	F.1, F.4, H.4, I.2, I.5	C.2, C.3, D.1, H.2
	constraints	buffer, end of wing, prioritisation, corridors or rooms lit, reception, number of entrances.	reception, number of entrances, direction, one entrance	Isolation rooms, linking of rooms, direction, one entrance
	requirements in achieve healing environment goals	prioritise acoustic solutions in following prioritisation: 1. spatial design 2. <i>low-tech</i> building physics 3. <i>high-tech</i> building physics/MEP	overview spatial configurations in relation to size of building envelope	prioritise room temperature/air-quality solutions in following prioritisation: 1. spatial design 2. <i>low-tech</i> building physics 3. <i>high-tech</i> building physics/MEP
	requirements in achieve healing environment goals	prioritise acoustics <u>and</u> daylight solution on basis of life-cycle costing	overview spatial configurations in relation to size of building envelope	research cost-efficient measures for maintaining temperature and air-quality in rooms

## Capacity Requirements

old situation (AMC):

- 20 IC-beds, 4 HC-beds and 4 MC-beds
- 8 neonatologists and 5 fellows
- 3-4 assistants, mostly doctors in training

new situation (AMC + VUmc), assumed:

- 40 IC-beds, 8 HC-beds and 8 MC-beds
- 16 neonatologists and 10 fellows
- 6-8 assistants, mostly doctors in training



<b>Clinical Rooms</b>	
<b>IC procedure room</b>	Room for complicated surgical procedures, continual respiratory support, or other intensive interventions (White, 2012).
space	minimum 33.5 m2 (White, 2012)
quantity	2
acoustics	placed away from the patient rooms; glass should be limited only for visualisation
(day)lighting	no daylighting needed
routing	close proximity to other IC rooms of the hospital
privacy	distinct, controlled area immediately adjacent to perinatal services
<b>Single Family room (IC)</b>	Room for care for medically unstable or critically ill newborns requiring constant nursing (White, 2012).
space	minimum 16m2 (White, 2012)
quantity	40
acoustics	placed away from operative rooms; walls built in obtuse angles to dissipate sound
(day)lighting	separate light sources for infant and mother
routing	close proximity to the birthing unit of the hospital
privacy	minimising traffic flow past each room
<b>Single Family room (HC)</b>	Room where patients can be cared for more extensively than on a normal ward, but not to the point of intensive care
space	minimum 16m2 (White, 2012)
quantity	8
acoustics	placed away from operative rooms; walls built in obtuse angles to dissipate sound
(day)lighting	separate light sources for infant and mother
routing	close proximity to the birthing unit of the hospital
privacy	minimising traffic flow past each room
<b>Single Family room (MC)</b>	In this facility, parents can look after their own infants with some supervision from trained Neonatal Unit staff.
space	minimum 16m2 (White, 2012)
quantity	8
acoustics	placed away from operative rooms; walls built in obtuse angles to dissipate sound
(day)lighting	separate light sources for infant and mother
routing	close proximity to the birthing unit of the hospital
privacy	minimising traffic flow past each room
<b>Laboratory</b>	Near patient testing is essential for the progressive Neonatal Unit. It is standard to be able to test examples within the confines of the Neonatal Unit
space	minimum 40 m2 (White, 2012)
quantity	1
acoustics	placed away from the patient rooms; glass should be limited only for visualisation
(day)lighting	no daylighting needed
routing	efficient in and outgoing of personnel
privacy	distinct, controlled area
<b>Pharmacy</b>	Many Units are served by a central Pharmacy in the hospital. A central room can be used for preparation of drugs.
space	minimum 20 m2 (White, 2012)
quantity	1
acoustics	no specific demands
(day)lighting	no daylighting needed
routing	efficient in and outgoing of personnel
privacy	distinct controlled area

Additional Demands for	
<b>special care</b>	Rooms which are allocated to special care, and which are not to be used at any time for intensive care functions
<b>Resuscitation</b>	Each room should therefore have a designated area for resuscitation containing an open radiant-heated cot or resuscitaire, with appropriate facilities
<b>Inpatient treatment</b>	A tertiary referral centre requires a treatment room to carry out laser therapy for retinopathy of prematurity. The room should be fully provided for intensive care.
<b>Outpatient treatment</b>	Many NICUs offer a daily “drop-in” clinic for unscheduled patients. An outpatient treatment room can be placed close to the NICU entrance,
Administrative Work Areas	
Reception	the organisational centre of the unit: here families are greeted, telephone calls are received, specimens are uplifted, results delivered, and letters are sent and received.
space	no specific requirements
quantity	desks for 2 receptionists
acoustics	no specific demands
(day)lighting	clearly visible; open and lit area
routing	located in close proximity and direct visibility of the infant care area
privacy	overlooking in and outgoing visitors
Unit Office	Next to the Reception Area, the Unit Office will be one of the most frequently used areas of the Neonatal Unit and therefore deserves extra planning according to the Unit's needs.
space	no specific requirements
quantity	4 desks
acoustics	silent and comfortable work area
(day)lighting	daylit office space
routing	located in close proximity to the laboratory
privacy	
(Family) Supporting Offices	Every Neonatal Unit needs to be supported by dedicated staff offices. In these, members of staff or relatives can have confidential discussions with senior staff.
space	16 - 20 m <sup>2</sup>
quantity	2 conversation rooms
acoustics	silent and comfortable
(day)lighting	daylit meeting room
routing	located away from the main routes
privacy	minimising traffic flow past each room
Seminar room, meeting room and skills lab	In small Neonatal Units seminars and meetings may be held in the same room.
space	+ - 20 m <sup>2</sup>
quantity	In large Units two separate rooms are required (White, 2012)
acoustics	silent and comfortable
(day)lighting	daylit meeting room
routing	located away from the main routes
privacy	minimising traffic flow past room
Library	The library should have extensive shelving containing medical and nursing textbooks and journals.
space	+ - 40 m <sup>2</sup>
quantity	There should be two worktops with two work stations in each. All four computers should have Internet connections. (White, 2012)
acoustics	silent and comfortable
(day)lighting	daylit meeting room
routing	located away from the main routes
privacy	minimising traffic flow past room

# Final Conclusion

MQ

*“How can a NICU design be made, in which the architect foresees on technical and spatial requirements to create an architectural design based on the principles of Healing Environment?”*

First, the architect has to find the technical and spatial objectives that serve the concept of Healing Environment, and that conflict in an architectural design for NICU. Trade-offs have to be made on level of rooms (e.g. for the issue of acoustic comfort versus daylighting/safety), other trade-offs are made on level of configuration of rooms (e.g. for the issue of temperature and air quality versus routing and logistics).

Secondly, the architect has to find the spatial and technical constraints that will come to the table when designing a NICU, by means of a precedent study. By researching different layouts, it can be seen which trade-offs can be considered, and which quality themes they serve: e.g. a careful trade-off should be made between placing the patient rooms on the outside of the floor (providing daylight for the patient) or placing the corridor on the outside (providing daylight for family/visitors).

Lastly, for finally coming to a programme of requirements for a NICU design, first directives have to be established. These directives concern design options, that are the result of a trade-off between quality themes. Issues of objectives that conflict (i.e. acoustic comfort versus daylight/safety, routing and logistics versus privacy, safety and security, temperature and air quality versus routing and logistics) can be ordered on a scale which presents what spatial or technical solution fits best for the particular room, configuration of rooms or zones.

In conclusion, the architectural design for a high-technological Neonatal IC Unit on basis of of Healing Environment demands for a stepwise approach that starts with accomodating principles of Healing Environment with Quality Themes for the Built Environment, and using spatial and technical constraints from precedents to set up directives which can be input for a programme of requirements.

# Research in Perspective

This research contributes to the understanding of complex architectural design solutions for a hospital building. As this research shows, designing a NICU demands for a scientific or systematic approach.

Research into a more scientific approach to architecture is imperative. The outlined complexity of hospital/health care centres brings together a functional design that has to convene the very specific demands (in this case, an ill newborn child). With an incremental demand for complex health care that delivers high quality at an affordable price (Grift & Velden, 2013) hospital architects need to rethink design solutions, in order to face the current challenges in health care.



Entrance Area NICU (Corbett, 2014)

# Limitations

The main limitations of the methodology of the research can be described as follows:

- Literature choice is limited. I used literature arbitrarily. It can be argued that using the variables from literature study does not fulfil the requirement of construct validity (Yin, 1998).
- Interviews have produced an internal validation of the above-mentioned arbitrary decisions, and made a contemplation of healing environment principles possible. However, these do not go into detail and cannot directly be extrapolated to other projects (external validity)
- The method used for collection of data may have been biased. This might be due to the theoretical preparation of the interviews. In addition to the methodological limitation, there are also longitudinal constraints. The time available to conduct my research was constrained by due dates and interviewees' availability.
- This thesis research does not provide external validity so as that its research results can be extrapolated to other hospital departments.

# Further Research

This research brought many interesting topics to the table; below mentioned two are highlighted:

- Designing on basis of Healing Environment: extrapolating the research to architectural designs for other hospital departments.
- Conflicts between Quality Themes for the Built Environment: research how conflicts (e.g. acoustic comfort versus daylighting/safety) pertain in other hospital departments and how these are interrelated.



Single-Family Rooms (Burpee & McDade, 2011)



# References

- Bird, D., Bostic, T., Taylor, M., & Zhou, S. (2011). CAYUGA MEDICAL CENTER: NEONATAL INTENSIVE CARE UNIT PROJECT REPORT.
- Carthey, J. F. (2013). Australasian Health Facility Guidelines-results of a user survey. *Facilities*, 31(13/14), 2-2.
- Clocquet, R. (2013). Toekomstige gebruikswaarde ziekenhuisgebouwen. *TVVL Magazine*, 3, 3.
- Evitts, E. A. (2007). Rethinking the E.R.: Hospital Emergency Department Plans. Retrieved March 19, 2015, from [http://www.architectmagazine.com/design/buildings/rethinking-the-er-hospital-emergency-department-plans\\_o](http://www.architectmagazine.com/design/buildings/rethinking-the-er-hospital-emergency-department-plans_o)
- Franck, C. (2013). The Use of Precedent in Design. Retrieved 31 May, 2015, from <http://www.slideshare.net/cghfranck/aibd-first-tuesday-precedent>
- Gooding, J. S., Cooper, L. G., Blaine, A. I., Franck, L. S., Howse, J. L., & Berns, S. D. (2011). Family support and family-centered care in the neonatal intensive care unit: origins, advances, impact. Paper presented at the Seminars in perinatology.
- Grift, G. C., & Velden, J. M. H. v. d. (2013). Naar een Alliantie AMC-VUmc. In VU medisch centrum (VUmc & Academisch Medisch Centrum Universiteit van Amsterdam (AMC (Eds.). Amsterdam.
- Hardy, N. P. (2005). Cost and Design Analysis of Neonatal Intensive Care Units: Comparing Single Family Room, Double-Occupancy, Open-Bay, and Combination Settings for Best Design Practices. University of Florida.
- Harris, D., Shepley, M., White, R., Kolberg, K., & Harrell, J. (2006). The impact of single family room design on patients and caregivers: executive summary. *Journal of Perinatology*, 26, S38-S48.
- Joseph, A. (2006). The impact of light on outcomes in healthcare settings: Center for Health Design.
- McCauley, K., & Irwin, R. S. (2006). Changing the work environment in intensive care units to achieve patient-focused care: the time has come. *American Journal of Critical Care*, 15(6), 541-548.
- Niemeijer, C. (2012). De toegevoegde waarde van architectuur: Eburon Uitgeverij BV.
- Pati, D., Harvey, T., & Cason, C. (2008). Inpatient unit flexibility design characteristics of a successful flexible unit. *Environment and Behavior*, 40(2), 205-232.
- Seppänen, O., & Fisk, W. J. (2004). Summary of human responses to ventilation. *Indoor Air*, 14(s7), 102-118.
- Sprow, R. (2012). Planning Hospitals of the Future. Designing Hospitals of the Future, Prism Publications.
- Stichler, J. F. (2001). Creating healing environments in critical care units. *Critical care nursing quarterly*, 24(3), 1-20.
- Thomas, L. (2010). Flexibility & Adaptability in Hospital Design & Construction.
- Valk, O. (2015). Thesis Interview 'fusion AMC-VUmc' In J. v. d. Ven (Ed.), MSc Architectural Engineering. Amsterdam.
- Wachman, E. M., & Lahav, A. (2011). The effects of noise on preterm infants in the NICU. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, 96(4), F305-F309.
- Yin. (2003). Applications of case study research (applied social research Methods). Series, 4th edn. Thousand Oaks: Sage Publications.
- Zimring, C., Joseph, A., & Choudhary, R. (2004). The role of the physical environment in the hospital of the 21st century: A once-in-a-lifetime opportunity. Concord, CA: The Center for Health Design.

# List of Figures

- Acoustic Bulletin. (2015). Sound Environment improved in NICU at UZ Leuven. Retrieved June 13, 2015, from [https://www.youtube.com/watch?v=jFp11myuLgo&ab\\_channel=acousticbulletin](https://www.youtube.com/watch?v=jFp11myuLgo&ab_channel=acousticbulletin)
- Acoustic Pearls. (2014). open space acoustic system. Retrieved June 13, 2015, from <http://www.architonic.com/ntsht/acousticpearls-architects-open-space-acoustic-system-more-space-in-modern-offices/7000722>
- Alpha Acoustiki. (2015). Vibration Suspension for Hospital Buildings. Retrieved June 13, 2015, from <http://antivibration-systems.com/showcase/vibration-control-products-mep-hva/>
- Ashford and St Peter's Hospitals. (2014). Privacy for Family Visiting the Infant Retrieved June 13, 2015, from <http://www.asph-maternity.org/options-for-birth/neonatal-care>
- Ashford and St Peter's Hospitals. (2014). Privacy for Family Visiting the Infant Retrieved June 13, 2015, from <http://www.asph-maternity.org/options-for-birth/neonatal-care>
- Audimute. (2014). Fabric Sound Panels. Retrieved June 13, 2015, from [http://houseplans-living.com/link-decorative-fabric-wall-covering-acoustic-soundproof-and\\_aHR0cDovL3d3dy5hdWRpbXV0ZWJjb3VzdGljcGFuZWxzLmNvbS9zb3VuZC1wYW5lbHM=](http://houseplans-living.com/link-decorative-fabric-wall-covering-acoustic-soundproof-and_aHR0cDovL3d3dy5hdWRpbXV0ZWJjb3VzdGljcGFuZWxzLmNvbS9zb3VuZC1wYW5lbHM=)
- Bon Secour Health System. (2015). Surgery in a NICU Operative Room Retrieved June 13, 2015, from <http://bshr.com/find-a-facility-bon-secours-depaul-medical-center-bon-secours-depaul-virtual-tour.html>
- Burpee & McDade. (2011). Single-Family Rooms. Retrieved June 13, 2015, from <http://aahfoundation.org/research/completed-research-initiatives/>
- Care New England. (2011). NICU Layout Providence, Rhode Island. Retrieved June 13, 2015, from <http://www.womenandinfants.org/newbornhealth/nicu/our-nicu-history.cfm>
- Children's Hospital Colorado. (2015). NICU Entrance. Retrieved June 13, 2015, from <http://virtualtour.childrenscolorado.org/virtualtour/NICU>
- Christner. (2014). Corridor Neonatal IC Unit. Retrieved June 13, 2015, from <http://christnerinc.com/work/markets/mercy-st.-louis-childrens-hospital>
- Community Memorial Hospital. (2008). Contact with the Newborn in an Incubator. Retrieved June 13, 2015, from <http://www.cmhshealth.org/distinction/mch/nicu.shtml>
- cooper. (2011). Lighting in Single Family Room. Retrieved June 13, 2015, from <http://www.healthcaredesignmagazine.com/news-item/perkins-eastman-celebrates-completion-nicu-connecticut>
- Corbett. (2014). Entrance Area NICU Retrieved June 13, 2015, from <http://architecture49.com/en/what-we-do/projects/women-and-newborn-hospital-health-sciences-centre/>
- Coverall. (2014). NICU handwashing. Retrieved June 13, 2015, from <http://blog.coverall.com/poll-germs-hospitals/#sthash.Lkef-WYyo.dpbs>
- Craig Aukland / Fotohaus. (2011). Dyson Centre for Neonatal Care, Bath. Retrieved June 13, 2015, from <http://www.e-architect.co.uk/england/dyson-centre-neonatal-care-bath>
- de Vaan, C. (2015). Arup NICU proposal Retrieved June 13, 2015, from <https://www.dignityhealth.org/las-vegas/services/labor-and-delivery/nicus>
- Dignity Health. (2012). NICU Double-Room Monitoring'. Retrieved June 13, 2015, from <https://www.dignityhealth.org/las-vegas/services/labor-and-delivery/nicus>
- EGM. (2013). Entrance Ikazia Hospital. Retrieved June 13, 2015, from <http://www.egm.nl/nl/project/54/ikazia-ziekenhuis>
- Fairview. (2015). Handwashing Stations Preventing Infection. Retrieved June 13, 2015, from <https://www.fairview.org/HealthLibrary/Article/88165>
- Flooring Advisor. (2013). NICU flooring. Retrieved June 13, 2015, from <http://theflooringadvisor.org/home/archdesigners/arch-design-feature-of-the-month/>
- gm-design ltd. (2014). shading devices patient rooms. Retrieved June 13, 2015, from <http://newbornsvietnam.org/what-we-do>
- Gutierrez. (2013). Handwashing Station NICU. Retrieved June 13, 2015, from <http://www.wakemed.org/landing.cfm?id=2714>
- Hamilton Health. (2015). single-family room. Retrieved June 13, 2015, from <http://www.hamiltonhealth.com/NICU>
- Harper. (2013). Separate Light Sources. Retrieved June 13, 2015, from <http://hcahealthcare.com>
- Health, S. J. (2015). Temperature Comfort in a NICU Room for patient and family. Retrieved June 13, 2015, from <http://www>

stjudemedicalcenter.org/Our-Services/Maternity-Services/Virtual-Tour.aspx

- Heraud-Parker, K. v. (2013). C Max Acoustic Ceiling Tiles. Retrieved June 13, 2015, from <http://www.tr-interiorsystems.co.nz/c-max-acoustic-ceiling-tiles-used-in-the-christchurch-hospital-amau-ward-upgrade/>
- Hospital, G. R. (2012). NICU operative room. Retrieved June 13, 2015, from <http://www.grhosp.on.ca/Surgicalsuite>
- Howorth Air Technology. (2014). Clean Room Technology. Retrieved June 13, 2015, from [http://www.cleanroomtechnology.com/news/article\\_page/Biosphere\\_contains\\_hospital\\_acquired\\_infections\\_in\\_24\\_hours/99617](http://www.cleanroomtechnology.com/news/article_page/Biosphere_contains_hospital_acquired_infections_in_24_hours/99617)
- I. C. Thomasson Associates. (2007). one source of light visible in NICU room. Retrieved June 13, 2015, from <http://www.ichthomasson.com/cms/University+of+Tennessee+Knoxville+Medical+Center/112.html>
- Knight Architects. (2014). Overview on the NICU floor. Retrieved June 13, 2015, from <http://www.knightarchitects.com/News>
- Mahle & Kinday. (2008). A view of the nurse station surrounding private NICU rooms. Retrieved June 13, 2015, from <http://www.healthcaredesignmagazine.com/building-ideas/design-neonatal-intensive-care-units-sensitivity?page=show>
- Medical Air Solutions. (2015). Ceiling Air Purification Systems for Positive Pressure. Retrieved June 13, 2015, from <http://www.medicalairsolutions.com/APS-Systems.htm>
- Moeller, N. (2014). Hospital Quiet Zone. Retrieved June 13, 2015, from <http://www.constructionspecifier.com/hospital-quiet-zone/>
- Mohns (2013). [Woman, Mother and Child Centre of MMC Veldhoven].
- Pinstopin. (2014). Obtuse Angle. Retrieved June 13, 2015, from <http://www.pinstopin.com/obtuse-angle/>
- Renfrew Group International. (2011). Airborne-infection isolation room. Retrieved June 13, 2015, from <http://www.mtbeurope.info/news/2011/1110013.htm>
- Rowley. (2010). Privacy for Mother and Child in NICU Room. Retrieved June 13, 2015, from [http://www.ormc.org/hospital\\_services/womenshealth-rowley-family-birthing-center.aspx](http://www.ormc.org/hospital_services/womenshealth-rowley-family-birthing-center.aspx)
- Shepley, M. M. (2014). Design for Pediatric and Neonatal Critical Care: Routledge.
- Shoji & Saito. (2014). responsive lighting design solution for the delicate needs of a critical care environment Retrieved June 13, 2015, from <http://www.illumni.co/2014-iald-award-winners-award-citation-hospitality-light-nicu-nagoya-daini-red-cross-hospital-lightdesign-inc/>
- Shrimad Rajchandra. (2015). NICU procedure lighting. Retrieved June 13, 2015, from <http://www.shrimadrajchandramission.org/news-media/seva-activities/srlc-nov-update-679.htm>
- Smith Seckman Reid. (2015). The significance of the nursing station hub is visually communicated with framing structures and lighting from above and below. Retrieved June 13, 2015, from <http://www.elplighting.com/projects/medical-nicu2.php>
- Terrace, R. (2012). Infant Room. Retrieved June 13, 2015, from <http://www.matermothers.org.au/hospitals/mater-mothers-private-brisbane>
- University of Connecticut Health Centre. (2009). Treatment of a newborn in an incubator Retrieved June 13 2015, from <http://neonatal.uchc.edu/contact/index.html>
- UZ Leuven. (2014). Hospital Department Critical Services (including NICU). Retrieved June 13, 2015, from <http://nieuws.kuleuven.be/node/9791>
- van den Berg, A. E. (2005). Health impacts of healing environments. A review of evidence for benefits of nature, daylight, fresh air, and quiet in healthcare settings. Univ. Medical Center Groningen, Wageningen.
- Visser & Smit Bouw. (2014). Healing Environment in Emma Children's Hospital. Retrieved June 13, 2015, from <http://www.visserensmitbouw.nl/nl/projecten/detail/metamorfose-emma-kinderziekenhuis-amc>
- Wechsler Linden. (2015). Mother and Child Care in a NICU. Retrieved June 13, 2015, from <http://www.wsj.com/articles/what-parents-can-do-to-help-preemies-1428940972>
- Whyte. (2009). Transport to Specialised Neonatal Facilities. Retrieved June 13, 2015, from <http://www.aboutkidshealth.ca/en/resourcecentres/prematurebabies/aboutprematurebabies/prematurelabourandbirth/pages/transport-to-specialized-neonatal-facilities.aspx>
- Wilson, N. (2013). Patient-Centred Care Retrieved June 13 2015, from <http://forces4quality.org/node/6347>
- WKZ. (2013). Entrance Wilhelmina Children's Hospital. Retrieved June 13, 2015, from <http://www.hetwkz-kind.nl/hoezitdat/het-ziekenhuis/>