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ICU Environment Design
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Improved ICU Design

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1 Introduction

This document contains the research done by Maartje van Roosmalen, Master student of the department Physics of the Built Environment and of the department Architecture at Eindhoven University of Technology and intern at Arup Amsterdam, in collaboration with the University Medical Centre Groningen (UMCG), on effects of the environment on patients' sleep disruption in Intensive Care Units (ICUs).

The research plan is defined in 1.afstudeerplan_30102009.doc. Research phase 1, which is completed as part of Master Project 3 can be used as reference material for this research. It includes literature research on the effect of the environment on patients' health and comfort and literature research on ICU guidelines. This document is research phase 2 and describes the analytic analysis, the measurement set-up and the measurement results of this research. Research phase 3 describes the implementation of the knowledge derived from phase 1 and phase 2 into (simulations of) designs of healing ICUs.

The order of steps to design and simulate an improved ICU design determines the structure of this report and is as follows.

1. Linking Analysis to Improvement Suggestions
2. Compare Simulation Results of Initial Environment with Measurement Results
3. Compare Simulation Results of Initial & Improved Environment
4. Compare Simulation Results of Improved Environment with Guidelines
5. Summary

2 Linking Analysis to Improvement Suggestions

This chapter describes the aspects of environmental design I focus on in the suggestions for improvement. This includes problem indications and design solution proposals related to the visual -, acoustic -, and spatial environment, that are based on a combination of literature research and measurement results.

2.1 Focus

The aim is to design an ICU unit that improves the patient sleep pattern. Designing ICUs we should keep in mind that good evidence-based design does not cost extra money, as simple design modifications can make significant difference, but will show significant savings over the life-cycle of the building, as well as improving the quality of life for all occupants [Law'03]. Nowadays doctors aim for a constant BIS level, blood pressure and heartbeat, which do not fluctuate, in contrast to the human biorhythm. In this ICU design proposal we design for normal fluctuations, encouraging positive distractions and contact with natural rhythms, but making sure that the medical process is not influenced in a negative way. Therefore, we compare the performance of the proposed ICU design with the ergonomic requirements of ICU designs as given in guidelines.

As the visual -, acoustic -, and spatial environment were of most influence to the patient sleep pattern in our measurements, we focus on these in providing improvement suggestions. We aim to design a generic concept for the average patient, where the average patient is defined as the average of all patients measured by us. The focus is on the influence of the following aspects of the visual -, acoustic -, and spatial environment on the sleep pattern of patients at the ICU.

Visual Environment:

- General/background lighting vs. task lighting vs. ambient lighting vs. night lighting
- Location and intensity of light in general
- Light color, color temperature (soft warm light for relaxing, cool light for activation), illuminance, luminance, etc.
• Choice of lamp type related to output in terms of lighting performance and effect of the appearance on the interior design and in terms of energy consumption
• Distribution of light over the room surfaces
• Illumination of particular areas or tasks
• Avoidance of visual disability or discomfort due to glare
• Changes in the visual environment
• Choices, controllability, and provision for selective switching or dimming (e.g. individual changes of light intensity/color by the patient)
• Non-visual factors
• Technical lighting needs and the necessity of lighting for hospital employees (e.g. at night)

Acoustic Environment:
• Environmental design and materials, e.g. application of sound absorbing materials, layout (busy passageways near patients head), etc.
• Noise from existing apparatus and their arrangement with their direct environment, e.g. by changing flooring
• We do not focus on the change of apparatus to less sound producing apparatus
• We do not focus on education for staff to be more quiet, or on designing schedules for checks, food, etc. though these improvements might be mentioned

Spatial Environment
• Size, number, height, location and orientation of windows, location and orientation of the bed, and positive and negative distractions.

As well as considering the physical design, a critical program that integrates the family and other healing measures is essential to the milieu of a healing environment. Furthermore, some environmental interventions appeared to be more successful than organizational interventions like staff education or quiet hours [Gas’89] [Moo’98] [Wal’00] [Zim’08]. Therefore, our research is limited to environmental design only. Possible improvements of the visual, acoustic and spatial environment are given in the next section.

2.2 Visual Environment

Therapeutic Lighting: Lighting for health and wellbeing

The old emphasis on lighting for visibility alone has given way to a more comprehensive model for lighting quality. It must meet many human needs; integrate with the architecture; respect the environment, and take into account economic circumstances. In recent years, awareness has grown of the scientific basis for how light influences human biology, behaviour, and health. In the context of wellbeing and performance, the most important hormonal rhythms stem from melatonin (the “sleeping hormone”) and cortisol (the “stress hormone”). Losing synchronisation between these can lead to physiological and psychological problems. Research in fields ranging from night-shift working to jet lag cure have concluded that light is the primary time controller of our biological clock, and thus directly influences mood, alertness, tiredness and motivation. The biological effect of light is not steered directly by the illuminance on the working plane, but by light entering the eye. Visually, light is only needed when and for as long as one “views”. Biologically, however, the time when the light (or darkness) is received and its duration play an essential role in our circadian rhythm. Research has however shown that there is no correlation between individuals and the timing characteristics of individual circadian rhythms. What is common is that in any interior environment occupied for a significant length of time, be it workplace, education, healthcare or leisure space, a balance of activating and relaxing moments is required. The colour and light distribution of the artificial lighting together may help to create
these moments and adaptability of the lighting scheme could be a key to the space’s ideal wellbeing lighting. Health clinics and hospital buildings have particular and demanding lighting needs and must function equally well by night and day. Proper distribution and level of illumination, along with good colour rendering properties of the light source are prerequisites in providing a good visual environment for medical staff routinely assessing the health of the patients, in performing surgery and its attendant disciplines. Natural light can promote health and has a positive effect on the healing process. Daylight is, however, highly variable and can bring problems of overheating, glare and reflections on display screen equipment. A wide range of shading solutions for the control and distribution of natural light can be developed to respond to the needs of users. Maintenance is a key issue in the design of electric lighting systems for most healthcare buildings. Equally, because of the extended operating hours of such facilities, a low energy approach to lighting can show big dividends in reducing running costs for healthcare clients worldwide. Example designs with therapeutic lighting are shown in the following figures.

Kaiser Medical Center, Fresno, CA, USA  
Great Ormond Street Hospital, London, UK  
[Florence Lam, Arup Healthcare, Therapeutic Environments]

The following design solutions are proposed to improve the visual environment:

**Lighting**

- **Problem/Issue:** Research indicates that many ICU designs lack sufficient daylight. Access to natural light is one of the few physical environmental attributes that has been linked by research with higher staff and patient satisfaction. This finding suggests that the right **quantity of natural light** is needed in staff working areas and in patient rooms. [Zim'08] For patients, exposure to daylight has been found to reduce pain, the amount of pain medications that they use, and the incidence of depression, and for certain types of patients, it also may reduce length of stay. A considerable body of rigorous evidence indicates that exposure to light — daylight or bright artificial light — is effective in reducing depression and improving mood.

- **Design Solution:** Site planning and the orientation of patient rooms in healthcare facilities should be carefully considered to ensure abundant daylight and avoid situations where some buildings block light for others. Larger windows in patient rooms not only provide natural light, but they also have the potential benefit of offering views of nature and should be considered in the design process. Additional daylight providers at facades or roof could be considered, such as light shelves, light ducts, light pipes, etc. to increase the quantity of daylight.

- **Problem/Issue:** Not only the quantity but also the **quality of daylight** exposure is associated with several patient and staff outcomes in healthcare settings. Adequate lighting has been identified as one component affecting patients' overall satisfaction with their hospital stays. Also, daylight positively influences the 24-hour circadian rhythm, it provides the patient with a sense of time and connects the patient to the environment. The color temperature of the daylight and the spectrum of the daylight influence the quality of the daylight. Tinted glazing changes the spectrum of the daylight and therefore reduces the quality of the daylight, as full spectrum daylight best resembles the natural environment. In colder climates warm white color temperatures are preferred to create a warm atmosphere.
• **Design solution:** These findings underline the importance of building orientation and site planning in new healthcare projects in terms of quality of light as well. It should be noted that Northern oriented windows provide, cool, white daylight while other orientations provide preferred warm white daylight that creates a warmer, more homely atmosphere. Warm white full-spectrum light is best derived from natural daylight and can be achieved through clear windows facing East, South and West, skylights, and atriums [Maz'02] [Sta'05].

• **Problem/Issue:** Static light environments do not fluctuate with the human biorhythm.

• **Design solutions:** Vary daylight according to sky type to create a more natural light environment:
  - Prisms
  - Solar tracing louvers or other sun-shading
  - Integrated daylight regulation via intelligent armatures
  - Light shelves
  - Light tubes
  - Etc.

If artificial lighting is required, even artificial lighting should vary over the time of the day and night to simulate a natural environment. This natural environment starts with increasing brightness in the morning (using e.g. the Philips wake up light). Research on patients suffering from depression found that patients in rooms with more morning daylight had shorter lengths of stay than patients in rooms without morning sunlight. During the day, patients should be exposed to adequate natural light or bright artificial lighting when natural light is not available. Lighting during the day varies little, as does the outdoor environment under influence of changing weather conditions. Lighting levels during the night should be decreased significantly as does the outdoor environment.

• **Problem/Issue:** The ICU is typically bright, featuring primarily harsh artificial lighting during the day and night. Many critical care clinicians fear that reduced quantity of artificial light at night will compromise patient care, but that view has not been supported by the research. As a major contributor to normal circadian rhythm, the amount of light that patients are exposed to at different times of day can affect sleep quality. It has been suggested that secondary to inappropriate light exposure, a dyssynchronisation of melatonin secretion with subsequent alteration of the ‘biological clock’ may contribute to sleep disturbances and delirium in critically ill patients. Although light is a vital element of a healing environment, continuous light even during the night disrupts the natural circadian cycle and contributes to drops in melatonin levels. Melatonin helps to facilitate sleep, and decreased levels can cause impairment in sleep patterns, which can then lead to delirium in critically ill patients [Fon’01]. Without the influences of day and night, the human body’s natural circadian rhythms are disturbed, which can result in disorientation, delirium, or even ICU psychosis, which may lengthen or jeopardize a patient's recovery [Sta’05]. Studies have shown that decreasing noise and turning the lights down decrease patient's anxiety, which with other factors decreases the incidence of delirium.

• **Design solution:** One study on reducing light and sound in neonatal ICUs by [Wal’01] found that modest changes, such as turning off fluorescent lights, covering incubators, and installing low-level patient-centered lighting, did not adversely affect patient safety but did increase staff satisfaction. They recommended to find a balance between brightness requirements and preferences for patients. Designs should include lower brightness in patient rooms at night if possible; lights should be dimmed long enough to ensure good sleep. However, the amount and timing of light in healthcare settings should be tailored to the activities that take place in them. In
general, sufficient lighting is beneficial to both patients and staff. Reduced lighting at night is preferred near patients and bright lighting is preferred in areas where staff performs critical tasks such as medication dispensing. Research has found that medication-dispensing errors are lower when the level of work-surface lighting is relatively high, compared to situations with lower levels of lighting. While other areas of the hospital have not been tested, it is logical to infer that bright lighting would also be useful in other places where precision is called for. So to allow higher light levels at certain places in the patient room, lighting with certain light cut off angles should be applied, which does not increase the ceiling luminance. They should be positioned such in the ceiling that the light does not directly fall on the head of the patient, but that it falls everywhere else so that medical staff can do their work properly.

![Figure: Plan and section with positioning of this cut-off lighting](image)

**Problem/Issue:** However, not all light-related interventions are successful. Another intervention study implemented guidelines to control nighttime light levels, and this resulted in significantly lower mean light disturbance intensity and shorter periods with high light levels [Wal'00]. However, these changes were accompanied by greater variation in light levels, which could disturb patients' sleep patterns.

**Design solution:** Control nighttime light levels such that changes in artificial light quantity occur gradually such that they are hard to notice, as patients often wake up due to changes in light intensity. These gradual changes can still allow control of nighttime light levels, thus reducing the mean light disturbance intensity and providing shorter periods with high light levels. Design details such as flexible light controls with various lighting intensities might be considered. Use lighting devices which, once you switch them on, slowly increase in intensity (such as the Philips wake up light), so that there is no immediate change and the patient doesn’t notice the slow change.

**Problem/Issue:** Light has healing properties, and light therapy has been instituted as part of the treatment plans of many diseases. Many forms of light exist, and a variety of therapies that use light are being studied. Photodynamic therapy is being tested at the Baylor Research Foundation in the treatment of viruses, and light therapy is being used to treat seasonal affective disorder and insomnia [Stå'05]. [Ulù'04] report that climate and sunlight not only direct circadian rhythms, but can also influence a patient's length of stay. One study of unipolar and bipolar disorder patients demonstrated a decreased length of stay of 3.67 days when patients were assigned a brighter room during the day. One study examined the impact of simulated bright daylight applying increased quantity of artificial light during the day in a north-facing room with limited natural light, affixing to the bed a lamp that was turned on at 10:00 a.m. and off at 5:00 p.m. [Wak’01]. Findings suggested that hospitalized elderly patients experienced better deep sleep at night when they were exposed to the artificial diurnal daylight compared to when they had darker daytime conditions. Bright light (natural and artificial) can improve health outcomes such as depression reduction, agitation, sleep, circadian rest-activity rhythms, length of stay in demented patients, and SAD (difference between morning and evening light). [Ulù’05]
• **Design solution:** Simulate higher daylight levels in darker rooms, such as north-facing rooms, using additional artificial full spectrum lighting during the day.

• **Problem/Issue:** Research indicates that many ICU designs lack proper exposure to **qualitative good artificial light**. A considerable body of rigorous evidence indicates that exposure to full-spectrum light — daylight or bright artificial light — is effective in reducing depression and improving mood. The ICU is typically devoid of full-spectrum light, featuring primarily harsh artificial lighting. Artificial lighting is predominately fluorescent and produces visual fatigue and headaches [Fon’01].

• **Design Solution:** Full-spectrum lighting fixtures are a reasonable alternative if natural daylight is not available [Maz’02] [Sta’05].

• **Problem/Issue:** Besides lack of full-spectrum light the color temperature of ICU lighting is often not adjusted to patient needs and therefore provides a **cold atmosphere**. The ICU is usually full of cool white light, as this keeps medical staff awake during their work, just as it activates patients while they are supposed to rest. One study involving school children and the effects of standard cool-white fluorescent lighting and full-spectrum light showed that the children in the classroom with full-spectrum lighting had academic and behavioral improvement one month after installation of this lighting. The report also stated that classrooms with the cool-white fluorescent lighting had more children with hyperactivity, irritability, fatigue, and attention problems. Furthermore, full-spectrum light produces less reaction to cortisol and ACTH stress hormones.

• **Design solution:** Artificial lighting with warm white color temperatures, so lower K.

**View/Aesthetics – Color, View, Environmental Landscape & Art for Healing [CCM’95]**

• **Problem/Issue:** Many studies have concluded that cool colors have a tendency to calm, whereas warm colors excite.

• **Design solution:** The Society of Critical Care Medicine recommends using calming colors that promote rest in critical care units [Fon’01]. Blues, greens, and violet are appropriate, because they have healing and calming influences and are stress-reducing colors. Reds, orange, and yellow colors should be avoided, because they induce excitement, increase blood pressure, and can cause fatigue [Sta’05].

• **Problem/Issue:** Many ICUs are designed without windows or position the patient’s bed in such a manner that it does not allow a view of the window. [Tur’01] cites Ernesto Machado’s experience during his father’s hospitalization in a cancer care centre. Machado spent many hours in a windowless waiting area, where he was appalled by the water-stained ceiling and the lack of a pleasant view. An example of conflicts of staff and patient requirements is the need for views out of buildings with the need to ensure clinical adjacencies. Ultimately, a hospital designed entirely around clinical adjacency principles becomes deeper in plan and offers less opportunity for views and daylight.

• **Design solution:** This experience inspired Machado to develop a product that would simulate a window view. This ‘virtual window’ for health-care facilities actually looks like a window for windowless rooms. It can be installed in the wall or ceiling and brings the healing power of water and nature into the stressful hospital environment.

• **Design solution:** Design to give patients, staff and visitors direct views out of buildings by changing the orientation of the bed or window. Patients who have views out actually recover more quickly, as daylight results in chemical changes in our bodies that enable our self-healing systems to operate more effectively. Some of the research here is remarkably detailed, even suggesting that there are differences between having morning as opposed to afternoon sunlight. Again this principle can be applied sensibly across a wide spectrum of healthcare settings. Common sense tells us that patients waiting at a clinic where they may be
• **Problem/Issue:** Considerable research has examined the psychological and physiological effects of viewing real and simulated nature. Most available evidence is related to the impact of nature views on patients. There is also limited evidence suggesting that staff experience restorative benefits from views of nature or exposure to gardens.

  o **Pain.** Nature has been determined to be an effective positive distraction, which can reduce the perception of pain and thereby reduce the use of pain medications. Some studies combined simulated views of nature with nature sounds or classical music; these studies demonstrated greater impact on pain reduction, compared with when auditory distraction was not available.

  o **Length of Stay.** A direct relationship between exposure to nature views and reduced length of stay in a study of patients recovering from abdominal surgery was found in one study. More research in diverse settings with various types of patient populations is needed to examine the contribution of nature views to the overall healing process and their effect on length of stay.

  o **Patient Stress.** Strong studies have found that exposing patients to nature lessens stress and anxiety.

• **Design solution:** Design to give patients, visitors and staff contact with nature – ideally and in the right climate this may be a matter of physical access. Views of nature are known to be therapeutic. Internal planting and even pictures can help significantly where gaining access to outdoors is not possible or sensible. Gardens in healthcare environments – calming in themselves, but also have mechanisms such as fostering access to social support and providing opportunities for positive escape and sense of control with respect to stressful clinical settings. [Ulr’05] If a real garden isn’t possible than nature pictures can provide similar calming points. A peaceful nature scene is superlative in inducing feelings of calmness and safety [Sti’01]. [Ulr’93] in their landmark study on the effect of nature and abstract pictures on patients recovering from open-heart surgery, found that patients who viewed nature scenes had decreased lengths of stay, had lower blood pressure readings, and required less pain medication. These researchers also suggested that patients who viewed artwork of a brick wall instead of nature recovered more slowly. Clearly, not all art has a positive influence on patients’ healing and stress reduction. Provide (images of) nature as positive distraction to reduce stress, pain, anxiety and symptomatic distress + positive emotional and physiological changes. Questionnaire studies showed that bedridden patients assign especially high preference to having a hospital window view of nature. [Ulr’05]

• **Problem/Issue:** Patients often get bored in the hospital, as they are too weak to be able to read or watch TV properly, and they often cannot go out of bed. Therefore, visual positive distractions should be provided that are visible for the patient from the bed such that they don’t distract doctors.
• **Design solution:** Introduce light, color, nature and art into an environment to provide positive distractions—this may be paintings on the walls but it can also be sculpture and even the nature of the spaces themselves. However, it can also be performance. Thoughtful art is another healing measure that can introduce light, color, and nature into an environment. Artwork in the ICU has not been considered an important element of the essence of a healing environment in critical care rooms until recently. However, as the conscious design of critical care patient rooms has moved toward the creation of a healing environment, artwork, light, and color have been recognized as integral elements. [Nau’03] notes that a trigger effect is produced when art enhances the body-and-mind connection. Appropriate therapeutic art evokes positive thoughts, which increases the feeling of wellness. Many hospitals have artwork in the corridors and entrances; however, artwork has been frequently neglected or placed haphazardly in patients’ rooms [Nau’03]. Artwork in patient rooms should produce a restful, calm feeling for patients and families. Some hospitals have art programs that can be changed at will by the patients as well as patient artwork. [Fri’99] suggests that art for therapeutic purposes should be positive and should depict identifiable images; these images include caring human faces, people displaying gestures or nurturing, and calming sunny nature scenes with green vegetation instead of brown or orange landscapes. Specifically, patient rooms absent of a window view can benefit from artwork that depicts the essence of nature, color, and light [Sti’01]. Artwork that depicts chaotic impressions, ambiguity, and abstract pictures should be avoided, because these forms may make the patient feel more ill than if no art is present.

![Artwork in Hospital](image1)

- **Design solution:** As another technique for using color in the environment to provide positive distractions, [Sti’01] suggests creating painted ceilings for patients to view while they are lying in bed. [CCM’95] If patients stay for longer time, then the
location of the patient’s bed can be changed, so that the patient gets to see a different ceiling painting or ceiling projections can change.

Control

- **Problem/Issue:** Patients need to feel that they have some sense of control over the environment so as to reduce their stress. Empowering patients by giving them control over temperature, lighting, privacy, visitation, and the type and volume of music decreases stress and improves healing. [Ro‘04] reports that patients were more satisfied with their care, slept better, had lower blood pressure, and were less likely to be readmitted when hospitals took measures to reduce the hospital environmental stressors. [CCM’95]

- **Design solution:** Give all building occupants environmental comfort and, most importantly, **control over that comfort** – this most obviously involves heat and light. However it also includes sound and the time of positive distractions and social support, such as the time that visitors can come. Hospitals are notoriously noisy places. [Blo’05] has shown that patients in a cardiac unit had their heart rates significantly reduced by decreasing background sound levels. Giving patients bed head controls of lights, blinds, curtains and doors is really very cheap to do and remarkably effective in reducing stress levels. Besides thermal, visual and acoustic comfort a good indoor air quality is beneficial.

![Control over temperature, sound, visitors, and light](image)

**Figure: Control over temperature, sound, visitors, and light**

### 2.3 Acoustic Environment

**Therapeutic Acoustics: Acoustics for health and wellbeing**

‘Designing a critical care environment that supports a healing atmosphere by reducing ambient noises takes into consideration many design elements, such as flooring, ceiling material, and doors and nursing station placement’ [Maz’02]. In addition to designing critical care units and rooms to create an atmosphere that is conductive to healing, there are other healing measures to consider.

![Arup SoundLab and Nightingale Acoustics, Basildon Cardiothoracic Centre, England, UK](image)

**Figure: Arup SoundLab and Nightingale Acoustics, Basildon Cardiothoracic Centre, England, UK [Nick Boulter, Chris Field and Adrian Popplewell, Arup Healthcare, Therapeutic Environments]**

**Environmental Design/ Equipment**

- **Problem/Issue:** Recent research indicates that patient recovery times and healing rates are significantly influenced by the noise levels within wards. There is emerging
evidence of quantifiable benefit in terms of reduced stay and reduced costs associated with good acoustic design and reduced noise.

- **Design solution:** Other research suggests that reducing noise levels can influence patient outcomes in other ways, such as nurses being less likely to make errors when they are less distracted by extraneous noise [Maz’02], [CCM’95]

- **Problem/Issue:** There is an amount of hypothesis to show that psychoacoustics is linked to the healing environment i.e. the more rest a patient gets the more efficient the body becomes to positively support the recovery process. There is however little in the way of tangible evidence to support the hypothesis that is easily available. Ambient noise levels, as well as peak levels, are much higher than levels recommended by the United States Environmental Protection Agency (EPA) and the World Health Organization (WHO). Recommendations are that LAeq is less than 40-45dB during day, and less than 35dB during the night. [Arup1] The foregoing discussion makes it clear that hospitals are far too noisy, and that noise in combination with acoustically poor environmental surfaces and multi-bed patient rooms worsens stress and other outcomes. Studies have shown that decreasing noise and turning the lights down decrease patient’s anxiety, which with other factors decreases the incidence of delirium.

- **Design solution:** There are effective environmental approaches available to quiet healthcare settings, which can be more successful than organizational interventions such as staff education or establishing quiet hours [Gas’89] [Moo’98] [Wal’00]. The most important design measure to reduce noise for inpatients appears to be single-bed rooms. In this regard, the research literature indicates that noise levels are lower in single- than multibed rooms [Gab’03] [Sou’95] [Yin’92]. The major advantage of single-bed rooms is reflected in Press Ganey's national satisfaction survey, which obtained data from 2.1 million patients in 1,462 facilities during 2003. Results showed that satisfaction with noise levels was on average 11.2% higher for patients in single-bed rooms than for those in multi-bed rooms; this pattern held across all patient categories and for different ages, genders, and facility sizes and types [Pre’03]. This is an extremely large difference, considering that it can be difficult for hospitals to increase satisfaction scores by even two or three percentage points.

- Providing single-bed rooms as opposed to multi-bed rooms can also lower noise levels and improve sleep quality. For multi-bed rooms in medium- and high-acuity units, most noises stem from the presence of other patients, whether caused by visitors, staff caring for other patients, or patient sounds such as coughing, crying out, and rattling bedrails [Sou’95] [Yin’92]. One study of multi-bed bays in a children's hospital concluded that noise levels were so high that consideration should be given to abolishing open-bay rooms [Cou’94]. These findings also have important implications for patient sleep, because noises stemming from the presence of other patients can be the major cause of sleep loss in multi-bed rooms, [Sou’95] [Yin’92]. In the Finnish study mentioned previously, the presence of other patients was reported as one of the most disturbing factors [Kui’98]. [Gab’03] compared the effect of open areas and single rooms on noise levels and the sleep of six healthy volunteers in an ICU. The average noise level was higher (51 dB) in the open ICU than in the single room (43 dB), as were the respective peak levels (65 dB versus 54 dB). Furthermore, total sleep time in the single-bed room (9.5 hours) was greater than that in the open ICU (8.2 hours), although the number of arousals was similar in both settings [Zim’08].

- **Problem/Issue:** Sound reflections increase the noise level as compared to space with the same sound source but all sound absorption.

- **Design solution:** Installing high-performance sound-absorbing materials for environmental surfaces such as ceilings, floors and walls can reduce reverberation time or echoing, sound propagation, and noise intensity levels [Ber’01] [Hag’05]
Floor coverings that absorb sound should be used, keeping infection control, maintenance, and equipment movement needs under consideration. Ceiling soffits and baffles help reduce echoed sounds. Doorways should be offset, rather than being placed in symmetrically opposed positions, to reduce sound transmission. Counters, partitions, and glass doors are also effective in reducing noise levels. [CCM’95] Hag’05 examined the effects of sound-absorbing versus sound-reflecting ceiling materials in a coronary ICU by periodically changing the ceiling tiles. When the sound absorbing tiles were in place, patient rooms showed a 5–6 dB drop in sound levels and a reduction in reverberation time from 0.8 to 0.4 second, indicating better acoustic conditions. Patients also reported fewer awakenings caused by noise. Further, [Ber’01] showed that even if the noise level (dB) remains almost the same, the reduction in reverberation time achieved by sound-absorbing ceiling tiles can improve sleep quality. Meanwhile, even relatively low decibel levels (27–58 dB), when coupled with longer reverberation times (sound-reflecting ceiling), significantly increased arousals in healthy volunteers sleeping in patient rooms. These findings have disturbing implications, because most hospitals have nighttime sound peaks exceeding those of the patient rooms in the study. The effect of reducing reverberation time was studied in 12 subjects during sleep. EEG-arousals following specific sound stimuli were significantly reduced (p<0.007) when reverberation time was reduced with sound-absorbing ceiling-tiles. On average reverberation was reduced 0.124 seconds at similar sound levels. It is proposed that increased sound absorption, i.e. reduced reverberation time, by contributing to a better acoustic environment may reduce sound-induced sleep fragmentation [Ber’01].

- **Problem/Issue:** Hospitals are noisy places with numerous sources of noise, and historically they have been designed with sound-reflecting surfaces that worsen acoustic conditions and enable noises to echo and propagate over large areas.

- **Design Solutions:** Research has found that using noise-reducing finishes such as high-performance sound-absorbing ceiling tiles can reduce the noise in hospitals and benefit both patients and staff [Zim’08]. [Maz’02] recommends utilizing sound absorbent carpeting, acoustic ceilings, and floor tiles in heavy-traffic areas.
  
  o **Acoustically:** the RT was lower (improving RASTI), and the ambient noise levels were 5-6dBA lower [Maz’02].
  
  o **Patients had:** lower pulse amplitude, a smaller chance of rehospitalisation in 3 months, lower frequency of sleeping medication (beta-blockers) [Maz’02].
  
  o **Nursing staff found:** a better psychosocial work environment (less stress, strain, fatigue, etc.) [Maz’02].
  
  o **Patient Sleep.** Getting a good night's sleep is very important to patients' healing processes. Studies have found that the noise level in many hospitals is quite high even at night and that noise is a major cause of awakenings and poor sleep. For this reason, measures should be taken to reduce the reverberation time, sound propagation, and noise intensity level in patient rooms [Zim’08].
  
  o **Patient Privacy.** The use of sound-absorbing materials can also enhance patient privacy by reducing sound propagation and privacy breaches. When single-bed rooms are not available, as in many EDs, hard-wall partitions rather than curtains should be used to separate bed spaces; these should be extended all the way up to the support ceiling or deck to protect speech privacy [Zim’08].
  
  o **Patient Satisfaction.** Noise is one of the factors of the ambient environment that patients complain about most frequently. Research found that a reduced noise level in patient rooms has a positive impact on patient satisfaction. Patients treated in spaces with good acoustic performance...
considered staff attitude and care quality to be much better than those in spaces with poor acoustics [Zim’08].

- Patient Stress. In addition to worsening sleep quality, noise elevates psychological and physiological stress in patients. The use of sound-absorbing materials in patient rooms, in combination with reducing noise sources, can create a less stressful environment for patients [Zim’08].

- Staff Stress. Limited research has focused on the effects of noise on staff. A recent study found that improved room acoustics (facilitated by using sound-absorbing materials) positively affected the staff's perception of work demands and lowered their work pressure and strain [Zim’08].

**Design solution:** [Pet’00] suggests creating mini-workstations throughout the unit to reduce noise from conversations by dispersing staff away from a central station, where escalating voices can often be heard over the basal sound level of the unit.

**Design solution:** Other design proposals include small bedside televisions with a pillow speaker or headphones [Kah’98], earplugs or noise-canceling headsets, or therapeutic sounds either through small machines or a centralized ‘music’ station.

**Design solution:** Even simple actions such as closing the patient's door and having single-occupancy rooms can provide relief [Top’01]. So automatically closing doors could be useful.

**Design Solutions:** Recommendations have been made in a few instances to buy quieter equipment. Attention should also be given to noises that can be significantly reduced through judicious equipment purchases, such as purchasing delivery carts with rubber wheels, because they are quieter [Maz’02]. Biomedical testing of patient care equipment for noise impact and development of maintenance programs that review quieter operation of equipment and machinery are also recommended to decrease noise levels [Maz’02]. A study of noise in a neonatal intensive care unit showed that even modest modifications reduced noise by 50% [Wal’01]. Modifications of the unit included installation of acoustical material in monitor bays, carpet that was installed in high-traffic areas, weather stripping that was added to doors and drawers, metal trashcans that were replaced by rubber cans, and covers that were placed over incubators. Also turning pagers to vibrate, avoiding the use of overhead paging, turning of unused biomedical equipment, and modifying and repairing unnecessarily loud equipment [Pet’00].

**Problem/Issue:** Whilst this is important, we believe that as well as giving consideration to controlling the negative aspects of "noise", the beneficial properties of "sound" must also be investigated and implemented. Added to this are concerns about speech privacy and confidentiality, patient and staff comfort, and ease of communication between patient and doctor. Privacy is also an important factor in acoustic comfort as well as a human right, which is in part linked to the acoustic performance of internal partitions, but also providing appropriate sound levels. Whilst a clinical environment which is noisy can be uncomfortable for both patient and clinician, and hinder communication, an environment that is too quiet may compromise speech privacy from adjacent rooms.

**Design Solution:** Provide sound absorbing internal partitions between beds in a multi-patient room and between ICU and Nurse Station, to ensure speech privacy. Walls between rooms need to be sound proof but else can be very thin, like a (mat) glass panel.

**Therapeutic Sounds/ music therapy & People**

**Problem/Issue:** Signals from patient call systems, alarms from monitoring equipment, and telephones add to the sensory overload in critical care units. Without reducing their importance or sense of urgency, such signals should be
Improved Environmental ICU Design

modulated to a level that will alert staff members, yet be rendered less noxious. [CCM'95]

- **Design solution:** Apart from providing single rooms, another approach for quieting facilities and reducing stress is to eliminate noise sources, for example, by replacing overhead paging with a noiseless system and insulating pneumatic tubes and ice machines.

- **Design Solutions:** Primarily for hospital staff (and visitors to an extent): conscious efforts to be quieter have been shown to lower noise levels. Given that human behavior is one of the greatest contributors to offensive sound, the generation of unnecessary noise can be abated with modification of staff's behavior.

- **Design Solutions:** Schedule multiple types of care – say, respiratory therapy and a blood draw – for a single visit to minimize night-time interruptions

- **Design solution:** Along with facilitating staff behaviors that decrease unnecessary and noxious noises, therapeutic sounds can be introduced, such as music, heartbeat sound (especially in the neonatal ICU), pleasant sounds from nature like ocean waves and rain showers, or even ‘white noise’ that lightly stimulates the hearing receptors, making other background noises less obvious. [CCM'95] Therapeutic sound is one example, demonstrating that not all sounds affect patients negatively [Chl'00]. In fact, some sounds can sooth and calm. Certain rhythmic patterns of music have anxiolytic effects on human psychophysiology [Chl'00].

Music therapy, which is classified as a noninvasive nursing intervention, is used as an adjunct to medical therapies. Music, when used as relaxation therapy, has an even rhythm that duplicates the normal pulse beat of humans, is nonsyncopated, and is lyric free. Music as therapy can be used to harmonize with or to bring back in sync the body's own rhythms. Alternative therapies as music are recommended by Richards in a 2003 paper [Rub'USA TODAY]

- Entrainment occurs when two elements become synchronized with one another and vibrate at the same sound frequency. Entrainment with relaxing music and the body's rhythms induces a decrease in pulse rate, respiratory rate, metabolic rate, oxygen consumption, and blood pressure [Chl'00].

- Studies support the effect of entrainment in the critical care population. [CHl'00] studied the effects of music on mechanically ventilated patients in the ICU. Although there were many uncontrolled variables and the study was small, Chlan revealed that heart rate, respiratory rate, and anxiety level could be positively influenced by adjunctive music therapy. In a 2001 study of mechanically ventilated Chinese patients and the efficacy of music therapy in decreasing anxiety, [Won'01] could not replicate the decreased physiological responses found in [Chl'00]. Their inability to replicate results could be related to the small sample size in both studies. Incorporation of music therapy into the plan of care can also decrease a patient's perception of pain. A study at a Swedish hospital of 60 female patients undergoing gynecological laparoscopic surgery revealed that patients required less pain medication with music therapy [Iko'04].

- A complement to traditional music therapy is the use of psychoacoustic therapy as a noninvasive nursing intervention. Psychoacoustic therapy comprises harmonies of therapeutic tones [Sti'01]. Sounds of nature – such as birds, water, rain, and waves – integrated with soft classical music can also reduce the anxiety of family and visitors in critical care waiting areas. Whether therapeutic sounds are utilized as a therapy to synchronize body rhythms or to provide a distraction, they can be a meaningful stimulus that can alleviate boredom and produce harmony [Chl'00]. When employing music as a nursing intervention, it is more important to recognize that not all music can produce an anxiolytic effect. Listening to music as a nursing intervention, it is important to recognize that not all music can produce an
anxiolytic effect. Listening to music evokes emotions and feelings that are rooted in an individual's past experiences and personal preferences. More often than not, soothing and calm music produces the desired anxiolytic results [Won'01]. When providing music listening as a therapy, the patient's cultural, geographic, economic, religious, and educational characteristics and – most importantly – reaction to the therapy must be considered. It is essential to give the patient a sense of control and respect his or her personal music preferences – for example, by having family bring in CDs – when feasible to optimize music therapy. [CCM’95]

2.4 Spatial Environment

Critical Care Design Principles

I have designed various Intensive Care Unit layouts shown below. The attached table names each layout by four characters that indicate the following:

1 = single-patient vs. 2 = multi-patient
A = linear
1 = standard design vs. 2 = reverse design
A = incl. Visitors corridor vs. B = excl. Visitors corridor
e.g. 1A1B = single-patient room linear design with N.S. towards interior and excl. Visitors corridor

Legend:
Thick red arrow = no view outside
Thick orange arrow = indirect view outside
Thick green arrow = direct view outside
Thin red arrow = no visibility of patient's head
Thin orange arrow = patients head just visible
Thin green arrow = direct close frontal visibility of >0.5m around the patient's head
Green = space for staff
Yellow = space for visitors
Blue line = daylight provider
N.S. = nurse station
Purple = desk in nurse station

In [Law’03] a set of exemplar images of designs that get very high scores for each of the statements given in ASPECT, part of the NHS overall design assessment tool AEDET, is shown. In the book ICU 2010 exemplar ICU designs are given.
These are evaluated on the following performance goals:

1. Reduce travel time for staff
2. Prevent Disorientation
3. Good visibility
   a. Staff to patient
   b. Patient to staff
   c. Visitor to patient
4. Privacy
   a. Visual
   b. Acoustic
5. Provide a Good View
   a. Patient outside
   b. Staff outside
   c. Visitor outside
6. Minimize Energy loss
7. Increase social support

These aspects are described in further detail below to indicate why these aspects are important and how they can be achieved. The score of each design for each performance goal is summarized in the following table. Scores are multiplied with an importance factor, which have higher score for increasing importance:

1. Short term ergonomical reason
2. Ergonomical reason
3. Medical reason

Scores over or equal to 60 are highlighted in the attached table, indicating that for centralized nurse stations the horseshoe design with perimeter corridor has the highest score, and for decentralized nurse stations the design position of the nurse station partially integrated in the room layout.
LAYOUT DESIGN

- **Departmental relationships – Reduce Travel Time for Staff**
  
  - Behavioural mapping can be used to find out the routes that are walked often by people related to the ICU, and can therefore help in determining departmental relationships.
  
  - Critical care units should be close to emergency, close to surgery & recovery, close to Imaging, close to cath labs. Travel distance to telemetry beds or step-down beds is important. As these functions are located in the hospital, the nurse station is preferably located towards the inside of the ICU and the patients are positioned towards the perimeter of the ICU.

- **Routing – Prevent Disorientation**
  
  - **Problem/Issue:** Way finding problems, also called spatial disorientation, in hospitals are costly and stressful. [Ul'r’05]
  
  - **Design solution:** Create places that have **spatial legibility** – that is to say make places people understand and can find their way around in. Design so that there is some hierarchy of space, so that public and private places are clearly demarked, so that entrances and exits are obvious, and so that different parts of buildings have different qualities.
  
  - **Design solution:** Develop efficient wayfinding systems, such as external building cues that lead to the hospital, parking entry etc. and local information to make it easy to identify destinations, signage, logical room numbering, and comprehensible nomenclature for departments, and a proper global structure, as people tend to move along "integrated" routes: more accessible, they are fewer turns from all other routes in the hospital.

- **Unit size - Visibility**

Figure: Horizontal Departmental Relationships

Figure: Clear routing, expandable/shrinkable vs. dead ends, not flexible layout
For centralized nurse stations the ICU shape is partly determined by the number of beds [ICU 2010]. The optimum size of a unit is 8 to 12 beds since that is about the maximum number of patients you can put around a central nurse station and allow proper visualization. [ICU 2010 p.50] Per central doctor unit 8 beds are ideal. Spaces with less than 6 beds are very costly, though better for patients. The ICU layouts compared are all 8 bed units.

- **Geometry – Visibility vs. Walking distance vs. View**

  - Geometry\(^2\) is based on visibility of patients from a station, which includes the visibility of staff for patients, walking distance, and ability for patients and staff to have a view outside, and is dependent on centralization or decentralization of nurse stations. Besides, beds are legally required to classic shapes: semicircle, open box, ele and linear designs, as indicated in the following figure. The most important aspects to compare layouts on are:
    
    - **Visibility:**
      - Good visibility; triangle, horseshoe, circular, box, front & back
      - Bad visibility; linear, stagger
    
    - **Walking distance:**
      - Short walking distance; box, front & back
      - Average walking distance; triangle, horseshoe, circular
      - Long walking distance; linear, stagger
    
    - **View:**
      - Patient & Staff; horseshoe
      - Staff; linear, stagger, triangle, circular, box, front & back

  - Nurses prefer circular, front & back, or box geometry for centralized nurse stations because of visibility and short walking distance. However, the above overview indicates that the horseshoe shape is the best in terms of visibility, walking distance and view ability.

![Figure: Comparative geometries for centralized nurse stations](image)

\(^2\) Example ICU geometries are attached in the Appendix
• **Enclosures - Privacy vs. Observation (Visibility)**

  o **Problem/Issue:** Roommate is more often a source of stress rather than support. Staff talking disturbs patients and patients shouldn’t hear certain information.

  o **Design Solution:** Design to give patients **privacy, dignity and company** – design to enable them to be alone and to be with others when they wish to. Enable them to control their levels of privacy. Such a simple rule can be applied to be obvious setting of an acute hospital bed space, but it can also be applied to a waiting space in a primary care building. Thus, the best solution is to design meeting rooms and provide single-patient rooms, such that the patient has the choice of privacy or company whenever he/she wants it. The easiest and most effective way is to design single-patient rooms with openable/sliding walls/doors.

  o **Privacy** could be provided by:
    - Limited size of glass areas
    - Privacy curtain across an open door
    - Or a substation next to the room with window

  o **Direct view for proper observation** is indicated by sightlines
    - By law the staff should be able to see the patient. Though videography, telemetry monitoring, and transtelephonic monitoring allow staff to know exactly what’s going on in a patients’ room [ICU 2010 p.53], many medical staff members prefer direct view.
• Centralized vs. Decentralized Nurse Stations – Reduce walking distance
  o Problem/Issue: Staff spends lots of time on walking. Besides, when a patient is critically ill, the nurses aren’t in the central station, they are at the bedside, and they therefore discuss things near the patient, which likely results in privacy and noise concerns.
  o Design solution: Design to reduce staff walking and fatigue by designing decentralized nurse stations. Smaller, more distributed nurse stations and walking distances can be massively reduced and the amount of time a nurse spends with patients hugely increased especially if we also decentralize some of the facilities and storage. [Law’03] Design single-bed rooms with decentralized nurse stations. Decentralized nurse stations improve patient observation and safety. There are several options:
    ▪ Having fixed substations outside the door or one between every 2 rooms is called a fixed satellite station.
    ▪ Mobile decentralization for nurses is another option, where the small nurse station is on wheels and can be moved to any room to look into a couple of rooms.
    ▪ Charting inside each room is another possibility [ICU 2010 p.71]
    ▪ The most extreme option is the completely decentralized station in the Royal Alexandra Hospital in Canada, with camera’s as backup [ICU 2010 p.70]
UNIT DESIGN
Besides the in the beginning of this section described performance indicators related to layout design, the prevention of anxious feelings, the provision of positive distractions, and the creation of a homely feeling are other important performance indicators that are related to the unit design. Design methods to incorporate these performance indicators are described in more detail below.

- **Spatial Proportions – Prevent Anxious/ Claustrophobic Feelings**
  - **Problem/Issues:** Strange shapes in rooms (e.g. because of equipment) are disturbing for a good experience of space, they might create anxious feelings.
  - **Design solutions:** Design spaces according to spatial proportions as indicated in the following right most picture [Arup]. The spatial proportions should be within a certain ratio, while eliminating sharp corners or disturbing elements within the interior shape of the room. So in this case on the left two pictures we see that the room is either too wide or too high, while having the disturbing element of a box with cables. In the right picture we see better spatial proportions, where the box with cables is designed in such a way and such a position that it does not disturb the spatial proportions of the room.

![Figure: Improvement of spatial proportions in ICU's by Arup](image1)

- **Multi-patient & single-patient ICU Size - Prevent Claustrophobic Feelings**
  - **Single-patient room:** As indicated before, single-patient rooms are preferred. The single-patient room size should ideally be 4.5 to 5m head to toe, and 5 to 6m side to side. This means that the minimum 14m² has more than doubled.

![Figure: Based on AIA 1996: min. Dimensions: >3.6m clear, >14m², adding space for medical equipment, considering space required to provide access to the patient's head, considering the space required to move stretchers and equipment past the bed, and considering space to access on all sides results in a space with dimensions ranging 4.5 to 5m head to toe, and 5 to 6m side to side.](image2)

  - **Multi-patient room:** The area required per bed for multi-patient rooms is nearer to the minimum required 14m², as multi-patient rooms often don’t include family areas and the space required to move equipment around the bed can be shared with neighbouring beds.

- **Flexibility/ Custom Design – Acuity Adaptable:**
Problem: Every time you transfer a patient, it adds a half a day, to a full day, to the length of stay, and adds about $500 to the cost of care. So one way to keep costs and duration of stay down and increase patient safety and recovery is to decrease the number of transfers: [ICU 2010 p.13]

Design solution: Design to reduce transfers by designing acuity-adaptable rooms. The idea is that by adding & removing technologies the room can be adapted to the patient, so the patient doesn’t have to be moved all the time, e.g. the acuity-adaptable rooms ICU units in Portland, Oregon. Make all hospital rooms universal rooms that can support any level of care required without moving the patient. By attaching the various monitors the patient might need closer to the headwall, and increasing the gas outlets by adding them to rails or opening cabinets, you can make it an ICU room. [ICU 2010 p.41] Space will become less of an issue, because technology is decreasing in size.

- Layout is the same for single-patient ICU and normal single-patient room. Size difference is the addition of medical equipment for the ICU which can be hidden in a cupboard of 2.5x2.5x0.3m, so hardly any difference in size.
- Gas outlets and access to oxygen and suction are hidden behind pictures in these rooms
- Just by moving up panels and pictures, you can make the nice, serene, cosy, homely room into an ICU room

Figure: (left) Traditional private room 16.4m$^2$ vs. (right) Acuity adaptable room 26.38m$^2$ at the Methodist Hospital Indianapolis, Indiana, with medical equipment covered in cupboard at the head side of the bed if it is not used.

Problem: None of the patient in high acuity rooms need a toilet, only staff uses them to throw patients urine from the bedpan. However, in case needed, a toilet should be available in each room.

Design solution: Research indicates that type of toileting that caused least stress, least changes in blood pressure, and preferred by patients is the commode chair next to the bed (ADA sizing for toilets). You can put a privacy curtain around it, so that if someone is actually sitting on one, they might not be seen from the corridor.
Improved Environmental ICU Design

- **Life Support System – Prevent Anxious feelings & Reachability**

  - **Problem/Issues:** Visibility of equipment scares patients and visitors.
  - **Design solutions:** In [FMT’08], a proposal for a separation between medical equipment on the one side of the bed, and social or personal ‘equipment’ on the other side of the bed is tested and the results showed an increase in satisfaction by the child patients. This increase was due to the medical equipment not being visible too much for the patient and the visitors. An idea is to put curtains around the equipment, such that the employees can easily reach them, so open on the sides facing away from the bed, and closed on the sides facing the bed.

- **Problem/Issue:** Patients are often not reachable from the head side of the bed due to the position of medical equipment.

- **Design solution:** Life support systems are usually positioned on the wall behind the head, but the patient is more reachable from all sides if the power column is diagonally positioned, such that there is space at the headset after moving the bed 1m from the wall. An example of power columns is the dualpendant-mounted overhead columns, where each movable arm has extraordinary utility & flexibility.
**Figure:** Kern Critical Care Unit, Legacy Good Samaritan Hospital, Portland, OR: Epicare Careporter maintains uninterrupted power and gas supply to patients’ equipment, organizes and manages bedside equipment while coupled to the ceiling pendent, and transforms to compactly next with bed for transport.

- **Location of family area vs. Hospital area – Social Support**
  - **Problem/Issue:** Areas separate for families to talk to doctors and to talk to the patient don’t work but areas within the room of the patient might work. [ICU 2010 p.51]
  - **Design solution:** Evidence shows that levels of social interaction can be increased (and presumably beneficial social support too) by providing a space for visitors to sit/stay over near the patient in a single-patient room. This results in improved appetite, longer visits by family, and it enhances social interaction. To allow for easy cleaning furniture can be on wheels. Besides, small increase in the floor area of a single room to allow for a relative overnight bed brings enormous benefits that will easily repay the costs. It dramatically reduces the nurse call-button activity and patient falls, for example. [Law’03]

![Acuity-adaptable, Single Coronary Critical Care](image)

**Figure:** Acuity-adaptable, Single Coronary Critical Care with family zone [Ulr’08]

- **Problem/Issues:** Medical staff is often disturbed by and they therefore restrict visiting hours, thereby reducing social support.

- **Design solution:** To reduce disturbance of medical staff by visitors and thereby allow for flexible visiting times and increased social support, separate zones for visitors vs. staff are recommended.
Figure: Different zones

- **Design solution:** Options are:
  - Family area physically separated from rest of the room
  - Family area on one side of the bed, medical area on the other side
    - This includes two entrances, one from the inside/from the nurse station, and the other from the perimeter of the ICU/from the outside of the patient room, to prevent cross of transport.

- **Hospital bed position & orientation – Visibility & View**
  - **Problem/Issues:** Elimination of view outside leads to disorientation, sleep disorders and depressives.
  - **Design solution: Activate the patient by:**
    - Position of the bed
    - Angle of the bed head as compared to horizontal
    - Control over the environment

  A proposal for an improved layout is the following, where the patient can look outside (preferably at a square or another place where there is much activity and therefore distraction) and at the same time look through the open door at the activity (and noise) of the ICU employees. In case the patient prefers to rest, the door can be closed (blocking the noise and view), and the patient has more privacy.

- **Design solutions:** In case a view outside is not possible, a view inside an atrium or patio with e.g. a restaurant (with lots of activity) is a good distraction for the patient.
  - About 1.5m is needed on either side of the bed, and 1m on the head and feet side of the bed. The hospital bed should be oriented such that the patient can see the staff (and vise versa) and such that the patient can see outside.
Figure: Universal ICU (21.7m²), Little Company of Mary Hospital, Torrance, California, with space on each side of the bed

- **Window position, size and orientation – Positive Distractions & Homely**
  
  o Window position should preferably be starting at 1m height, to provide privacy for the space below 1m height. Windows should at least be 1m high, and wide enough and oriented to provide a proper view outside for both patient and staff. Window size should be limited to a certain size to provide privacy and to reduce solar heat gain. Window orientation is preferably towards South, as the sun is highest and it's easiest to provide shading while allowing an unblocked view outside. Window orientation to East and West is also good in terms of providing warm white daylight, just like the South orientation, however, for orientations East and West it's difficult to shade while allowing unblocked view outside, as the sun height varies over time. Orientation North is not recommended, as this provides cold white daylight and creates a darker, colder atmosphere in the patient room.

- **Home-look alike & Family Areas** [ICU 2010 p.73] – Calming & Homely
  
  o **Problem/Issue**: Current environmental designs are small, cold, functional and not supportive. Environmental changes that make a place more comfortable, aesthetically pleasant and informative relieve stress among patients and increase satisfaction with the quality of care.

  o **Design solutions**: Changes to the general layout, colour scheme, furniture, floor covering, curtains, and providing informational material and information displays results in positive environmental appraisals, improved mood, altered physiological state, and greater reported satisfaction.

  o The following are exemplar images of healing hospital single-patient and multi-patient rooms, with i.e. cleanable materials with calming colors and textures and variable lighting towards the back of the room.
Improved Environmental ICU Design
Figure: Comparison of Hospital Single-Patient Rooms
Figure: South Tees Hospitals NHS Trust, James Cook University Hospital, Middlesbrough, UK
3 Improved ICU Model

This chapter describes three models of improved ICUs:

- Multi-bed ICU
  - improvement of existing ICU where measurements were done
- Single-bed ICU for centralized vs. decentralized nurse stations
  - new design based on
    - literature research and measurements
    - performance comparison of layouts integrated with unit design recommendations

Improvements are related to the visual - and spatial environment, as the visual and acoustic environment seem to have a big influence on the sleep pattern according to literature research and the spatial environment determines the visual environment. To develop a solution product for the described problem, it should be made sure that the medical process is not influenced in a negative way. Therefore, simulation results of the improved design are compared with guidelines.

3.1 Multi-bed ICU Design

As no major changes can be applied for the renovation of the multi-bed ICU, the layout modifications are restricted to change in orientation of the patient bed and the monitor next to the bed which is used by medical staff, as these are modifications of the interior design only. This means that the Nurse Station will be at the same place. The orientation of the bed has rotated 90 degrees to the left as compared to the original design.
Summarizing the disadvantages of the original daylight design, I get the following:

- Glare caused by too high contrast in luminances between the work pane (computer) and the direct environment (window façade) for a clear sky model with and without sun-shading.
  - Therefore, preferably a change in orientation of the occupant and work pane would be a possible solution.
  - Besides, a different type of sun-shading is preferred, since for the existing sun-shading the window part below the sun-shading and the sun-shading cloth itself have a too high luminance as compared to the computer screen. An example is a series of horizontal rotatable louvers with diffuse reflecting coating on top applied over the whole window surface. For overcast sky the sun-shading can be taken away.

- Too little daylight deep in the room as compared to near the window; near the window we see a daylight factor of 25 to 35% with half or optimal clarity shading, whereas deeper in the room the daylight factor ranges from 2 to 4%. This does satisfy the requirement of minimal 1%. However, a somewhat higher daylight factor deeper in the room would save energy for artificial lighting for a longer time during the year.
  - Therefore, a light shelf would be a possible solution to direct the light deeper in the room and block the light near the façade.
As mentioned the façade of this measurement bed in the ICU is oriented towards south west – west, the angle of the light shelf with the façade should be flexible, since at the west the sun changes height and else the sunlight might enter the room below the light shelf. So the light shelf should be rotatable.

The angle of the light shelf is also dependent on the length to width ratio of the room, where deeper rooms need a light shelf that is tilted higher.

Using a horizontal light shelf located higher than the eyes of a standing person, the view of the person outside is not blocked.
- Instead of one light shelf, a series of horizontal rotatable louvers with a reflecting coating on top might be a solution to direct the light deeper in the room.

- Another possible solution, not implemented in the alternative design, would be to increase the reflection factor of the surfaces.

Therefore, an alternative design for the ICU has been made, which is evaluated using 'DIALux' and Radiance.

The first change is relating the daylight provider. The aim is to increase the amount of direct daylight deeper in the room by applying a light shelf and a highly reflective ceiling finishing which reflects the daylight deeper in the room. Increasing the window height as well will make this solution more effective. The following figures indicate the original situation and window height, and the alternative design.
Improved Environmental ICU Design

Figure: Original design multi-bed ICU (low window height)

Figure: Alternative design multi-bed ICU (high window, light shelf)

Also, the layout of the ICU is changed, such that the patient can look outside on one side and at the doctor on the other side. The computer rotates with the bed, such that the doctor does not look towards the window but sideways, to reduce the chance of glare. These figures indicate that from the curtain on the left till the curtain on the right there are 2 windows of 1230x1600mm for each bed.
Besides, the reflection factors of the surfaces could be increased to get more indirect light in the room.
The following figures show the original and the alternative design, with in the alternative design the thin horizontal line in the façade indicating the light shelf on the outside of the windows:

![Image: Old perspective multi-bed ICU with chair facing window vs. bed parallel to window]

![Image: Old perspective multi-bed ICU vs. Alternative perspective multi-bed ICU]

3.3 Artificial Lighting Design Multi-bed ICU

Summarizing the disadvantages of the original artificial light design, I get the following:

- Illuminance
  - All lighting designs satisfy the minimum illuminance requirements and the requirements of the uniformity index.
  - All light sources (including their cover/armature) do also satisfy the glare requirements. However, the lighting design for emergency cases or long term investigation gives a very high illuminance in the patient’s eyes.

  - Therefore, the aim is to get this illuminance just above 1000lux without causing glare or too strong light in the eyes of the patient. A solution is to let the light come from a light source at a different location, located in the existing horizontal beam above the patient’s
head – directed towards the chest of the patient, instead of the light source that is applied now right above the patient’s eyes.

- Glare/luminance contrast
  - Since there are no light sources within the direct view direction of the occupant, the direct light is not the cause for glare.
  - The too high contrast in luminances was caused by a small gap between the window frame and the clarity shading. By changing the orientation of the occupant, this too high contrast is solved, as can be seen in the design & advice for daylight.
  - Glare is also on the screen because of the emergency light that is located such that the light falls directly on the screen. Using the solution shown above, namely to re-locate the emergency light, might reduce this effect.

- Color rendering index
  - By changing the lights, for example the TLD to a TLD master, the color rendering index can improve from 50-70 to >90, and thereby satisfy the requirement.

3.4 Single-bed ICU Design

SINGLE-PATIENT & CENTRALIZED NURSE STATION
Figure: horseshoe ICU layout with centralized nurse station

Figure: horseshoe ICU layout with centralized nurse station
Figure: horseshoe ICU layout with centralized nurse station

Figure: horseshoe ICU layout with centralized nurse station: visitors approach through perimeter corridor
Figure: horseshoe ICU layout with centralized nurse station: nurse station
Figure: horseshoe ICU layout with centralized nurse station: nurse station

SINGLE – PATIENT & DECENTRALIZED NURSE STATION

Figure: ICU layout of single-patient rooms for decentralized nurse stations
Figure: ICU layout with decentralized nurse station: visibility. Orange = staff area, purple = patient area, pin = visitors area.

Figure: Suite layout of single-patient rooms applicable for centralized and decentralized nurse stations
3.1 Daylight Design Single-bed ICU

The daylight simulation results are attached in the appendix. They indicate that the average Daylight Factor is larger than 3, thus complying with requirements.

3.2 Artificial Lighting Design Single-bed ICU

3.2.1 Boundary Condition

The following boundary condition is given for the artificial lighting design of a single-patient ICU:

- Heating/Cooling/Ventilation
  - As designed and discussed with Mark van Piggelen (Arup), the best design for heating, cooling and ventilation of single-patient rooms is to provide general heating, cooling, and ventilation by means of concrete core activation and local heating, cooling and ventilation by means of a radiant panel above the patient bed.
  - This way the area where medical staff and visitors are can be somewhat cooler than the area where the patient is. Besides, radiant heating/cooling is more effective than heating/cooling of air in terms of energy consumption as we feel radiant heating/cooling more so less change in temperature is required.

- Lighting
  - No false ceiling (to hide wires) in combination with concrete core activation

3.2.2 Artificial Lighting Concept Proposals

Following the concept proposals for the artificial lighting design of a single-patient ICU:

- **Solution 1A:** Electricity supply built in ceiling. Inbuilt armatures in the concrete ceiling such that connections are still reachable but wires are inbuilt.
  - **Advantage:** Any location is possible for the light sources
  - **Advantage:** No reduction of room height if light sources are inbuilt
  - **Disadvantage:** Difficult to clean
    - Not if covered with e.g. softec lens
  - **Disadvantage:** Not flexible & Difficult to keep connections reachable
    - Unless a cylindrical armature is positioned on the ceiling, not in the ceiling

- **Solution 2:** Wires and armature behind alcove.
  - **Advantage:** Flexible
  - **Disadvantage:** Architectural design influenced by addition of an alcove
  - **Disadvantage:** Dust collection behind alcove

- **Solution 3:** Armature partly in the beam with electricity supply and medical equipment above the bed.
  - **Disadvantage:** Armatures are required at multiple places in the room, so this solution should be combined with another solution to provide lighting also elsewhere in the room.
  - **Advantage:** This beam is anyhow needed in the ICU.

- **Solution 4:** Lighting armatures in radiant panel inbuilt in partly false ceiling above the bed.
  - **Advantage:** Wires not visible behind false ceiling
  - **Advantage:** Flexible, easy to repair
  - **Advantage:** Extra use of empty space above partly false ceiling
o **Advantage:** Radiant panel in partly false ceiling is in middle of the room above the patient, therefore providing light around the patient, and not in the eyes of the patient (unless reading light is on)

o **Advantage:** In combination with lighting in alcove lighting in front of the top part of the windows provides an equal light distribution over the room.

o **Advantage:** Integrated lighting, heating, and ventilation design, as the ventilation unit is located above the radiant panel in the partly false ceiling.

Solution 1 and 3 are combined and worked out in more detail in Artificial Lighting Design Concept 1, in the following section. Concept 2 and 4 are combined and worked out in more detail in Artificial Lighting Design Concept 2.

### 3.2.3 Artificial Lighting Design Concept 1

Concept 1 is a combination of solution 1 and 3 as described in the previous section, and is further described as follows:

- **Calmness, no glare & good illuminance**
  - Dark ceiling
  - Armatures with diffuser

- **Illuminance levels:** adaptable for patient and for medical staff and comfortable for different users
  - General lighting: Multiple small light sources divided over the room
  - Reading light: TL-tube in the bottom of the beam above the patient head
  - Task lighting (for emergency): In the side of the beam above the patient head

- **Armature types:** for individual control and to create calmness
  - Dimmable lights

- **Light control:** for personal lighting and difference between day and night
  - Light switches near entrance and near the bed

#### General Lighting

![Figure: Erco Dark light armature with softec lens inbuilt in ceiling](image)

*Figure: Erco Dark light armature with softec lens inbuilt in ceiling*  
*Figure: Lamp on ceiling*

This Erco dark light armature looks dark even when the light is on. Only from the zone outside the 40° angle the clarity of the armature is visible.
Patient:
- No glare
- Calming: dark ceiling
- Controllable
- Homely: not visible

Visitors:
- Homely
- No ‘hospital’ ambience
- Addition of ambient lighting possible

Medical Staff:
- Sufficient light
- Light at the right place
- Day vs. night with same armature through dimmable light

Reading Light
Though patients at the ICU are hardly ever able to read, reading light should be provided for those who can read.

Task Lighting (Emergency)
Task lighting for medical staff should provide direct light on the body of the patient, without getting shadows on the patient’s body. This light can therefore only come from the ceiling or from the head side of the bed, as at all other sides of the bed the medical staff can block the light.
3.2.4 Artificial Lighting Design Concept 2

General Lighting

For general lighting multiple dimmable fluorescent lamps can be applied, e.g. the slotlight II (as the slotlight II has better light characteristics than slotlight I) of 28W with diameter T16 and number 42160023 of Zumtobel lighting with characteristics:

- Linearly equally distributed lighting; 3 lamps of each 1.172mm with small overlap over the full length of the wall
- Smaller tl-tube than original tl-tube
- Higher illuminance
- Medium to natural color appearance: color-appearance-index Ra = 65 to 96;
- Extra warm white light color to daylight white: color temperature 2700-6500K
- Limit number of powers, diversity of colors
- Also in u-shape in limited number of powers and light colors

The lamps are positioned in the frame as follows, such that there is no dark spot between two lamps.

Figure: Positioning of TL-tubes in frame, angle 5°

LEDs could be applied for ambient lighting and night lighting, for its ability to mix colors, if they are manufactured in future such that they produce less heat.

Figure: General lighting in single-patient ICU

Reading light

For this function a similar lamp type is applied as for task lighting for research, namely a compact fluorescent lamp, however, with a lower wattage, namely 18W. The task lighting should be flexible, such that the patient can read while sitting and while lying in the bed.
task lighting can be fixed to the head of the bed. A possible solution is Erco Lucy TC-T, 18W, 1200lm, nr. 33176.00.

Figure: Lucy task lighting

3.2.5 Artificial Nightlight Design Concept
Nightlight – LED in wall

Night light should not be positioned in the corner of the eyes of the patient, so not too high. Positions lower to the ground are preferred, as the function of night light is to light up the floor so people can see where to walk and where to find entrances to other places. The nightlights are therefore positioned on each side of the entrance to the corridor and the entrance to the bathroom. Nightlights are positioned at about 1m height in the non bearing walls separating patient rooms, and they are oriented towards the floor to prevent glare. Their position in non bearing walls makes them easy to replace/repair and easy to clean while glare is prevented by the softec lens. The nightlights are not visible for the patient if he/she lies down, but they are visible when the patient sits up in the bed (to get out of the

Figure: Reading light in patient room
bed) and for the medical staff walking around. The night lights provide equally distributed light near the floor.

Figure: LED 3.6W, floor washlight, e.g. Erco nr 44596.00

Figure: Nightlights in single-patient ICU
4 Simulation vs. Measurement vs. Guidelines

To make sure that the model is accurate, simulation results of the initial design are compared with the measurement results of the initial design. These results are compared with simulation results of the improved environment to check whether the proposed improvements really change the environment in the expected way. To assure compliance with guidelines, the simulation results of the improved design are compared with the requirements set by guidelines.

Only the visual environment is simulated. For the other environmental aspects in the second chapter indications have been given for improvement, and in this section an indication of the software that can be used to simulate these improvements is given for further research. IES can be used to simulate the thermal environment of the initial and improved design and to do CFD analysis to simulate the airflow of the initial and improved design. Dirac and Sabin can be used to do simple acoustic analysis of reverberation times.

4.1 Visual & Spatial Environment

DIALux is used to simulate the artificial lighting design and Radiance to simulate the daylight design.

4.1.1 Daylight Design

Comparison of Original Design and Alternative

The variant will be compared with the original design for the two sky models that I have done measurements for, namely the CIE overcast sky and the clear sky model.

CIE OVERCAST SKY

Visual comparison of contour plans

First, the variant is analyzed visually comparing figures with contours of the same illuminance. In the following figures we see that the light is distributed more equally over the room for the alternative design as compared to the original design. Therefore, there is less contrast in luminance and therefore less chance of glare, and less artificial light is needed over the year because of the higher illuminance deeper in the room. From the 2 white spots at the alternative plan for the overcast sky model we see the influence of the window frame, which splits the white spot of higher illuminance into two parts.
If we compare the luminance contour plans of the original design and the alternative design, we see that for the alternative design with light shelf the luminance contrast is less, since the luminance varies from 0-40cd/m², whereas for the old design the luminance contrast varies from 0-60cd/m².

Further, for both models we see that the CIE overcast sky gives a more or less symmetrical illuminance and luminance distribution over an axis perpendicular to the west facade.

**Daylight factor of old and alternative design**

**Daylight factor per measurement point**

The following results are obtained from a simulation of the initial and alternative daylight design of the ICU in DIALux. If we use the same grid for the simulation as used for the daylight measurements, we get the values indicated in purple in the following tables. The results of the daylight simulation of the original model are similar to the daylight measurement results, which are indicated in the daylight card.
Table: Illuminance per measurement point for DIALux initial model for no clarity shading measured at 0.85m height

<table>
<thead>
<tr>
<th>M</th>
<th>2.4</th>
<th>1330</th>
<th>632</th>
<th>479</th>
<th>197</th>
<th>133</th>
<th>97</th>
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<tbody>
<tr>
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<td>1344</td>
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<tr>
<td>1.5</td>
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<td>618</td>
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<tr>
<td>1.2</td>
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<td>614</td>
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<td>208</td>
<td>142</td>
<td>106</td>
<td></td>
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<tr>
<td>0.6</td>
<td>1394</td>
<td>636</td>
<td>330</td>
<td>211</td>
<td>144</td>
<td>105</td>
<td></td>
</tr>
</tbody>
</table>

Table: illuminance per measurement point for DIALux alternative model for no clarity shading measured at 0.85m height

<table>
<thead>
<tr>
<th>M</th>
<th>2.4</th>
<th>1064</th>
<th>776</th>
<th>506</th>
<th>359</th>
<th>230</th>
<th>173</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8</td>
<td>1035</td>
<td>775</td>
<td>530</td>
<td>365</td>
<td>242</td>
<td>186</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>1020</td>
<td>743</td>
<td>522</td>
<td>359</td>
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<td></td>
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<tr>
<td>1.2</td>
<td>1000</td>
<td>707</td>
<td>511</td>
<td>357</td>
<td>233</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>0.6</td>
<td>1083</td>
<td>765</td>
<td>433</td>
<td>321</td>
<td>225</td>
<td>171</td>
<td></td>
</tr>
</tbody>
</table>

The minimum illuminance is measured as 97lux and the maximum as 1394lux for the initial model, whereas for the alternative model this is respectively 171lux and 1083lux for no clarity shading. We see that the daylight is more spread out over the room, so there is less contrast and the room can do with less artificial light during the year. The uniformity ratio changed from u0=0.21 in the original design to u0 = 0.34 in the alternative design for no clarity shading, where only the alternative design satisfies the requirement of a uniformity factor of u0>0.3.

If we look at the curve from the daylight card we see that the illuminances of the alternative design are distributed more equally over the depth of the room.

**Figure: Comparison of illuminances at 0.85m height using the overcast sky model in the old and alternative model in DIALux**

**Average Daylight Factor**

To be able to compare the old design with the variant, the average horizontal illuminance is measured and simulated in the old design, namely 464,625lux and compared with the simulation of the variant design, which is 637,208lux.

Using this, the daylight factors are calculated and compared. The daylight factor, the ratio between the illuminance inside and the illuminance outside (in het vrije veld), is a measure for the amount of daylight entering the room. In practice the guidelines for the average daylight factor are used. In case the local ratio is 1%, the daylight amount at that place is considered just enough. At places where this value is not reached, additional artificial lighting is required over more or less the whole year. In practice an average daylight factor
between 2% and 5% turns out to be satisfactory. In this case only daylight is enough for a large amount of time. With higher daylight factors artificial lighting is not needed for a larger amount of time. However, we need to be conscious for a bigger change of glare and heat transmission.

The daylight factor is calculated using the illuminance outside and inside for a CIE overcast sky. We calculate the daylight factor as follows:

Daylight factor = illuminance inside/ illuminance outside * 100%

DF = \( \frac{E_i}{E_{vv}} \times 100\% \)

The average daylight factor is determined by taking the average illuminance of the illuminances measured at the regular measurement grid. To determine the local daylight factor in DIALux, the illuminance is calculated at the measurement points. The horizontal illuminance outside (also called ‘het vrije veld’ is in DIALux given as 7000 lux (March is winter situation). The average illuminance in the 3D model is calculated as 464.625lux. The average daylight factor is:

\[
\text{DF} = \frac{E_{i, gem}}{E_{vv}} \times 100 \%
\]

\[
\text{DF} = \frac{6000}{625.464} \times 100 = 9.1\%
\]

We see that the average daylight factor of 6.6% for the old design and 9.1% for the alternative design satisfy the requirement of minimal 1%, where the daylight factor of the new design is higher and therefore better.

CLEAR SKY

Illuminance and luminance for a clear sky model

As a last comparison method, the old and alternative design are compared for the illuminance and luminance for a clear sky model, to see if the alternative model reduces the luminance contrast without reducing the illuminance too much. The luminance contrast for the original design in the view direction of the occupant, as seen in the daylight card, is as follows.

Sun light:
- Optimal sun-shading
- No sun-shading

The luminance contrast for the alternative design in the view direction of the occupant is as follows.
Improved Environmental ICU Design

We see that the alternative design, with a luminance ranging from 49cd/m² to 420cd/m², does satisfy the requirement of a maximum luminance ratio of 1:3:10 in the view direction of the occupant, while the original design does not satisfy this requirement.

If we compare the illuminance in the original design (with sun-shading) and alternative design (with light shelf) at 0.85m height, with respectively 0.00=0.31 and 0.00=0.43, we see a similar difference for the clear sky model as seen for the overcast sky model, namely that the illuminance deeper in the room is much higher for the alternative model, while the illuminance near the façade is for both models similar.

The following figures show the location of the additional light source to increase the illuminance on the patient’s body without causing glare in the patient’s eyes. This method has been successfully applied in another ICU, as can be seen in the following figures. The
following table shows the simulation results, with $E_{\text{min}}=1019\text{lux}$ and $u_0=0.72$ in the emergency area, which indicate that this method makes sure that the design satisfies the requirement.

**Figure: Method to increase the illuminance on the patient's body.**

**Figure: Method applied in another ICU**

**Table: Illuminance per measurement point for general and emergency lighting in the alternative design**

<table>
<thead>
<tr>
<th>2.4</th>
<th>778</th>
<th>1027</th>
<th>1183</th>
<th>1135</th>
<th>818</th>
<th>565</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8</td>
<td>904</td>
<td>1250</td>
<td>1468</td>
<td>1382</td>
<td>1019</td>
<td>639</td>
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<td>1.2</td>
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<td>1461</td>
<td>1833</td>
<td>1740</td>
<td>1161</td>
<td>641</td>
</tr>
<tr>
<td>0.6</td>
<td>572</td>
<td>947</td>
<td>1195</td>
<td>1145</td>
<td>800</td>
<td>480</td>
</tr>
<tr>
<td>M</td>
<td>0.6</td>
<td>1.2</td>
<td>1.8</td>
<td>2.4</td>
<td>3.0</td>
<td>3.6</td>
</tr>
</tbody>
</table>
5 Summary & Conclusion

Improvements are proposed for the visual -, acoustic -, and spatial environment of ICUs, based on measurement results and literature research. A summary of unit design recommendations is provided in the following table. Various layouts are compared based on several performance indicators. The best layout is single patient rooms with decentralized nurse stations on the inside of the hospital and separation between staff and visitors. The horseshoe layout is the best layout for centralized nurse stations. The improvements of the visual- and spatial environment are implemented in a design for single patient room ICUs for centralized and decentralized nurse stations. The daylight and artificial lighting simulations of this design indicate that the performance of this design conforms requirements given in hospital guidelines, while reducing the amount of light falling on the patients’ face. Whether the design improves the patients’ sleep pattern should be measured in future work.

We may conclude that ICUs should be designed as single patient rooms with decentralized nurse stations or with centralized nurse stations in horseshoe layout, and that they should incorporate the healing design measures summarized in the following table. A lighting and spatial design as described in this report should be incorporated, as this will reduce the amount of light falling on the patient’s face and will therefore likely improve the patient’s comfort.
### Table: The critical environment; Traditional versus Healing [Kah’98] [Ber’04] [Pet’00] [Sti’01] [Law’03]

<table>
<thead>
<tr>
<th></th>
<th>TRADITIONAL</th>
<th>HEALING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical environment:</strong></td>
<td>Designs are utilitarian/sterile ambience, no flexibility in building modifications</td>
<td>Incorporates color and architectural interest, such as therapeutic art, nature Clear routing, adaptable to changes, expendable/easy to decrease in size. Utilize calming color schemes such as blues, greens, and violet. Apply warm and/or bright colors. Limit confrontation with illness as far as possible; Block view of medical equipment in case not in use (curtain/cupboard). Provide positive distractions; such as interesting views, interior design of the room, natural elements</td>
</tr>
<tr>
<td>Lack visual interest or esthetic appeal</td>
<td>Designs are based on patient’s needs</td>
<td>Designed to limit noise with sound absorbing materials such as carpet and acoustical tiles in high-traffic areas. Incorporates therapeutic music, psychoacoustic therapy, and nature sounds. Establish an official policy on noise standards and evaluate noise levels. Much of the noise pollution in the critical care setting is avoidable, and efforts might include setting pagers to vibrate rather than ring, reducing the number of unnecessary alarms, and limiting conversation and television noise during nighttime hours. [Tal’08] Test equipment for noise impact and implement a maintenance program</td>
</tr>
<tr>
<td>Noisy and chaotic</td>
<td>Designed to limit noise with sound absorbing materials such as carpet and acoustical tiles in high-traffic areas. Incorporates therapeutic music, psychoacoustic therapy, and nature sounds. Establish an official policy on noise standards and evaluate noise levels. Much of the noise pollution in the critical care setting is avoidable, and efforts might include setting pagers to vibrate rather than ring, reducing the number of unnecessary alarms, and limiting conversation and television noise during nighttime hours. [Tal’08] Test equipment for noise impact and implement a maintenance program</td>
<td>Full spectrum lighting, incorporates natural light and direct unblocked view Outdoor places of respite; to get fresh air and experience sunlight, eliminating unwanted heat gain/loss and glare. Position the patient to appreciate the view</td>
</tr>
<tr>
<td>Limits natural light or window view, too bright with low quality light</td>
<td>Full spectrum lighting, incorporates natural light and direct unblocked view Outdoor places of respite; to get fresh air and experience sunlight, eliminating unwanted heat gain/loss and glare. Position the patient to appreciate the view</td>
<td>Turning down lights as much as possible during the evening hours; Provide periods of low light for sleep</td>
</tr>
<tr>
<td>Limits privacy and family presence</td>
<td>Private rooms and family area</td>
<td>Decentralized; Use a mini-workstation to disperse staff</td>
</tr>
<tr>
<td>Limits patient's control</td>
<td>Offers option to give patient control over light, temperature, visiting, music and privacy</td>
<td>Liberalized visiting policy</td>
</tr>
<tr>
<td>Restrictive visiting policy</td>
<td>Liberalized visiting policy</td>
<td>Liberalized visiting policy</td>
</tr>
<tr>
<td>Centralized nurse station, not close to patient, so nurses stay in patient room and discuss patient matters there, no privacy + noise</td>
<td>Decentralized; Use a mini-workstation to disperse staff</td>
<td>Holistic with active involvement of patient and family in the plan of care, family-friendly program.</td>
</tr>
<tr>
<td><strong>Social environment:</strong></td>
<td>Holistic with active involvement of patient and family in the plan of care, family-friendly program.</td>
<td>Create contact-rooms; to prevent solitude and provide the opportunity for nurses to go from the nurse room to a different environment, and for patient to meet for social support.</td>
</tr>
<tr>
<td>Focus on healing, not on social support</td>
<td>Holistic with active involvement of patient and family in the plan of care, family-friendly program.</td>
<td>Holistic with active involvement of patient and family in the plan of care, family-friendly program.</td>
</tr>
<tr>
<td><strong>Healing measures:</strong></td>
<td>Holistic with active involvement of patient and family in the plan of care, family-friendly program.</td>
<td>Holistic with active involvement of patient and family in the plan of care, family-friendly program.</td>
</tr>
<tr>
<td>Allopathic</td>
<td>Integrates complementary therapy, such as aromatherapy, Pet therapy, performing arts, hypnosis, prayer and guided imagery, yoga and reiki, therapeutic touch</td>
<td>Integrates complementary therapy, such as aromatherapy, Pet therapy, performing arts, hypnosis, prayer and guided imagery, yoga and reiki, therapeutic touch</td>
</tr>
<tr>
<td>Symptomatic treatment</td>
<td>Incorporates body, mind and spirit</td>
<td>Incorporates body, mind and spirit</td>
</tr>
<tr>
<td>Lacks connection between patient’s experience and treatment plan</td>
<td>Connects patient’s experience and treatment through music, art, and aromatherapy</td>
<td>Connects patient’s experience and treatment through music, art, and aromatherapy</td>
</tr>
</tbody>
</table>