

# Design of healthcare structures by green standards

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**Abstract.** Global warming is real, and the healthcare industry is both a contributor and a victim. Also, physical setting and, in particular, sustainable design practices can support patient recovery during hospitalization. In the context of this paper, focus areas for design of green healthcare structures have been explored in detail. Herein, we are laying focus on understanding architecturally justified approaches of interior lighting in a healthcare setting. This paper also discusses design strategies to improve indoor air quality in hospitals and the current international research to improve indoor air quality are reported. Other focus areas like greenhouse keeping, use of green interior materials and landscaping are discussed. Data for the review was extracted from published books and diverse online sources with the help of the Google search engine. It was found that healthcare structures, being resource intensive establishments, consume vast amounts of energy, water, and construction materials to provide high quality care. It was also found that healthcare institutions, by adopting sustainable measures are capable of reducing their environmental footprint to a bigger extent, boost the wellbeing of healthcare staff and aid patient recovery.

## 1 Introduction

A green hospital is one that aims to be environment friendly, utilizes renewable resources, reduces waste by implementing green practices and enhances patient well-being. The concept of a green hospital works on the principle of the three R's – Reduce, Reuse and Recycle [1]. These hospitals are very innovative and reduce the emission of carbon to a large extent. Although the initial cost of construction for green hospitals are high, it has a long-term effect in reducing energy cost.

Global Warming being an emerging issue, it's of merit that every healthcare facility is designed and planned with a strong emphasis on Green Building Concepts, that not only serve to make designs sensitive to environmental problems but to also protect the ecological balance while at the same time fulfilling the required comfort and health conditions.

Research shows that poor waste disposal, prolonged and excessive use of hazardous products, toxic chemicals and medical technologies which emit harmful radiations in

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healthcare institutions are gradually and confidently harming the environment [2]. These are some of the important aspects that need to be considered by the hospital designing and planning companies anywhere in the world to ensure reduced or no harm to biodiversity.

Research shows that a well-designed healthcare building can actually to a greater extent boost the curing process. Increasingly therefore, architects are focusing on green strategies to enhance the positive impacts on patients and staff in hospitals. Design professionals need to know how their buildings will enhance the cure – through spatial and physical ambience [1].

Design of healthcare structures taking into consideration green standards comes with a myriad of benefits which include but not limited to:

- Faster patient recovery time thereby reducing the length of stay in the hospital,
- Eliminate Sick Building Syndrome (SBS) for both patients and staff,
- Reduce stress levels in hospital workers, which further improves quality of care,
- Optimum energy and water consumption means reduction in cost of operation,
- Employees are motivated and hence improve their quality of work and overall hospital performance,
- Reduction in operation cost by optimum consumption of power and water.

## **2 Focus areas in design of healthcare structures**

In Architectural Planning & Design of Green Hospitals, an overarching consideration is to ensure that the floor plate facilitates efficiency. An efficient floor plate facilitates efficiency [1]. An efficient floor plate design will reduce the construction foot print of a healthcare facility – thus benefitting both the owner (lowered construction cost) and the patient (fast smooth and the efficient transit through the hospital).

### **2.1 Lighting**

Owing to many factors, the need for medical facilities is constantly growing. New health care facilities are being built, and existing ones are being reconstructed or renovated to meet the growing demand and established health standards [2]. It's of significance to note that human beings synthesize approximately 90% of their body's requirement of vitamin-D, naturally – from the skin's exposure to sunlight. All these circumstances provide the opportunity to design and redesign the lighting to meet the needs of patients, visitors, medical staff and other personnel associated with healthcare. This new lighting concept advocates for use of green lighting fixtures, lamps and controls that save energy and are environment-friendly.

A good design of a healthcare facility should maximize day light and optimize the artificial lighting requirement. Day lighting refers to the controlled admission of natural light from the sky, both direct and diffused, into a building, so as to reduce the use of electrical energy for lighting [3].

In medical lighting design, gaining momentum is the trend of creating rooms with a warm and relaxing light, that further create an atmosphere that gives the impression of a residential building, rather than an institutional environment in which complicated rules and regulations apply. Corridors and waiting areas, have sconces and other decorative lamps integrated in the walls. The soft glow of the wall sconces and / or indirect lighting is more relaxing and helps the patient recover better because the sharp light from light bulbs and fluorescent tubes is avoided.

Corridors are another area where the lighting concept is being developed. The patient may derive discomfort in being pushed along the corridor on a stretcher, watching the rows

of bright fluorescent light bulbs and tubes flashing above their head [1]. To improve the perception of the patient, the designers choose the lighting in the corridors, which is indirect and makes the walls of light shine uniformly.

Elderly patients mean older eyes; and older eyes require brighter surfaces to facilitate safe movement in all medical facilities. Energy efficient wall washers, architecturally designed on one side of the corridor, can be used to light and define a vertical surface. The indirect lighting in the corridor provides a safe and user-friendly exit.

Fluorescent decorative fixtures with a golden diffuser can provide additional warmth to light from efficient lamps. Similarly, compact fluorescent downlights can achieve this result through the use of wheat-colored reflectors rather than the standard clear, anodized reflectors. All these are necessary if the intention to achieve energy efficiency and environmentally friendly attributes is to be realized.

These fluorescent lamps have the ability to emit less heat than incandescent lamps, a factor, which helps to lower air-conditioning costs. Incandescent light fixtures should be used on dimmers, as this further extends their lifetime. Long life metallic halide lamps, although not dimmable are becoming common for ambient lighting. Same is the case for induction lamps that have a long lamp life.

Use of light-emitting diode (LED) lighting is another green option that offers services for pretty long time. LED lights also emit if any, very low amounts of heat. These LED lights are recommended if helping one navigate their way through many buildings in a healthcare facility is anything to go by. LED light fixtures can also serve as night-lights in patient rooms [4].

Light from the sun is the cheapest and plays a vital role in the healing process and has been documented to provide both psychological and physiological benefits. The Green Guide for Health Care suggests that automatic daytime dimming controls should be used for light fixtures that are located 15 feet inside and 2 feet to either side of all windows, within 10 feet around all skylights, and within 10 feet from the exterior face of clerestories, to optimize the energy efficiency of the facility's lighting system. Light fixtures located farther into the room, away from the source of natural light, will not be affected by the daylight.

Large windows should be a part of the total hospital experience, from patient rooms, to public spaces, to staff quarters, to surgical rooms (Fig. 1). They however come with a disadvantage, they can increase heat loads. Installation of controlled shades on these large windows help regulate the amount of direct sunlight while still providing a wide view of the outside.

In ground-up construction projects, light shelves placed on exterior windows can be used to enhance the effects of daylighting into the interior spaces. The shelves reflect light, from the ceiling on the inside, into the room.

Green lighting design can be achieved efficiently and cost-effectively through the implementation of any of these lighting methods. Whether a fresh construction project, reconstruction or renovation project, these design concepts are reliable and can produce desired results [1].



**Fig. 1.** Natural lighting as in Lunder Building, Massachusetts General Hospital.

Artificial lighting is required in sensitive areas of the hospital – including operation theaters, medical dispensaries, interior corridors and passages [3]. However, with rising energy costs and high initial investment, it is imperative to reduce operational cost of lighting in hospitals – by combining natural lighting and artificial lighting.

**Table 1.** Recommended Lighting Levels for Healthcare Structures: (ASHRAE 90.1-2007).

Type of Room	LPD (Lighting Power Density) (W/sq.ft)
Emergency	2.7
Recovery	0.8
Nurse Station	1.0
Examination/Treatment	1.5
Pharmacy	1.2
Patient Room	0.7
Operating Room	2.2
Nursery	0.6
Medical Supply	1.4
Physical Therapy	0.9
Radiology	0.4
Laundry-Washing	0.6

The following are passive design aspects enhance natural lighting in hospitals:

- Design of glazing facades so as to have both view and Daylight,
- Installation of translucent skylights having soothing colors,
- Having transparent and operable openings to green courtyards,
- Taking into consideration of ledge seating at windows – engaging nature in the curative process.

Design aspects to enhance efficiency of artificial lighting in hospitals:

- Use occupancy sensors in passageways, storage rooms, labs, etc. [1],
- Installation of low-energy LED lighting to save on Indoor lighting energy cost (Up to 40%),
- Use task lights to provide illumination in task areas like consulting rooms, labs, wards [1].

## 2.2 Indoor Air Quality –Active and Passive Measures

IAQ is defined as the process of providing air which is comfortable in every way and does not cause negative health effects, disease or sickness in humans and is devoid of dust, smells, draughts and noise as much as possible [5].

Air quality at hospitals needs special precautions during design and maintenance stage to prevent infections from spreading. It is reported that 5% of all patients who go to hospitals for treatment will develop an infection while they are there (O'Neal C, 2000).

Studies show a direct relationship between certain concentrations of air pollutants with internal health problems, such as: allergies, asthma, bronchitis, pneumonia, lung cancer etc. [(Deloach, 2004), (Craig, 2003), (Health Canada Indoor air quality, 2005), (Hoskins, 2003)]

### 2.2.1 Strategies to improve indoor air quality in hospitals

Strict adherence to guidelines such as ASHRAE/, WHO, NADCA etc. during the design and maintenance stages. Performing constant and regular checks and correct ventilation standards to dilute and remove impurities [6]. Consider use of air purifiers or other methods to improve indoor air quality. Performing regular inspection and testing for gases, particles, microbiological etc. and taking immediate actions to rectify the problems if any. Providing local hooding with exhaust for bathrooms and kitchen [7]. Proper space planning, routine monitoring of various parameters of HVAC systems, proper maintenance of all parts of the system and regular inspection and cleaning of a.c ducts are some of the airborne infection control techniques. Apply techniques of elimination of contaminants at source itself [8].

During the design stage it's necessary to use special care for space design for infection control. Segregation of sterile areas, separate path for dirty materials movement, provision of staff change / wash areas, sealed rooms are few important factors to be considered during the space design as a strategy for infection control [5]. Examination of floor and wall surfaces for cleanability, regular "deep clean" after infectious patients left the site, measurement of air quality periodically and regular microbiological testing are some of routine monitoring strategies for infection control. Monitoring controls, indoor conditions, and pressure devices, regular filter, coil & drain cleaning, regular water testing, regular component replacement are the recommended maintenance strategy for infection control in a healthcare unit [9].

Creating awareness among the staffs, and publics about the importance of IAQ and encourage them as not to do the following:

- Bringing non-sterile objects into the room – particularly in designated clean areas,
- Opening windows – Frequent opening of windows allows external pollutants in,
- Not changing prescribed clothes before entering into the clean areas and avoids washing hands after touching the infectious items [9],
- Allowing too many visitors around patients.

To achieve an indoor environment of great quality advocated for by green standards, it's important to take into consideration the following provisions:

- Installation of permanent entry-way systems to capture dust particles like slotted systems, grates or grilles at all primary entrances,
- Use of certain species of indoor plants which produce oxygen while also at the same time reducing indoor foreign and harmful substances like Volatile Organic Compounds from air[10],
- Provision of spaces in the courtyard with native and adaptive plant species, which may not cause allergic reactions. This greatly improves fresh air circulation,
- 100% ban on use of Volatile Organic Compounds as constituent component of interior materials.

**Table 2.** Outdoor Fresh Air Requirements for Ventilation of Healthcare Facilities.

Applications	Estimated Occupancy/100 Sq. m	Outdoor Air Requirements		Comments
		CFM/Person	CFM/Sq.ft	
Patients Rooms	10	25		Procedures generating contaminants may require higher rates
Medical Procedure	20	15		
Operating Rooms	20	30		
Recovery and ICU	20	15		
Autopsy Rooms	20		0.5	Air shall not be re-circulated into other places
Physical Therapy	20	15		

### 2.3 Green House Keeping

The accumulated foreign substances, such as dust, soil and other pollutants on the surfaces of parts of the health care building, are one of the transmission routes through which infections find way into the facility [1]. Therefore, effective and efficient cleaning methods and schedules are necessary to maintain a clean and healthy environment in healthcare buildings. Today, green housekeeping policies and procedures increasingly focus on creating a positive environmental impact. Typical measures include:

- Underline cleaning products that are in compliance with environmental standards [11, 9].
- Provide training for personnel in the safe handling and disposal of hospital waste.
- Consider recycling where possible.

It is also important to consider that in summer insufficient insulation of roofs, walls and other elements of medical facilities can cause discomfort for patients due to the penetration of heat from the scorching sun. To eliminate this drawback, the use of insulation, such as extruded polystyrene, polyurethane foam in the shell of healthcare buildings, can significantly reduce energy consumption.

### 2.4 Clean and Green Interior Building Materials

Healthcare buildings may inadvertently contribute to illness exposing patients and staff to a host of pathogenic germs and toxins that enter the hospital premises through the medium of a large number of infected patients.

Interior surfaces of Healthcare Buildings should be from materials that are capable of repelling, resisting or even discouraging growth of pathogenic germs and bacteria on them. The construction market now prides itself with the availability of patented interior surfaces like countertops, tiles, vinyl flooring etc., that are resistant to bacterial and fungal growth (Fig.2).

Owing to the fact that copper offers great appearance and offers a good surface that can be touched without worrying concerns, the use of copper based interior materials for door handles, light switches, faucets, worktops is encouraged. Research shows that copper as a construction material offers a surface that is microbial resistant [7].

Of paramount significance too is the use of indoors and flooring which do not emit/absorb / re-release indoor pollutants such as Volatile Organic Compounds and dust [1].



**Fig. 2.** Clean and green interior materials as evidenced in Central Los Santos Medical Center, UK.

## 2.5 Gardens and Landscaping

Gardens and landscape are an aesthetic delight and promotes wellness of patients in hospitals (Fig. 3). Persons exposed to plants have higher levels of positive feelings (pleasantness, calm) as opposed to negative feelings of anger and fear.



**Fig. 3.** Landscape Spaces of Priory Hospital Glasgow, Scotland.

Several studies show that recovery from stress is faster and ends when patients are exposed to the natural environment than any other form of artificial environment.

With a growing understanding of the importance of the physical environment for the quality of hospital care, as well as for the health and safety of patients and staff, the outdoor spaces of hospitals, especially in rural areas and in greener areas, are considered a productive addition to reserved interior spaces to treat the patient and are traditionally referred [10].

As a result of this new, holistic approach to medicine which entails alleviating the fears and disorientation of patients that may hinder medical treatment, the healthcare buildings have come to be seen today as necessarily comforting and stress-free environment, designed and created with a broader, patient-oriented sense that encompasses both master planning and landscaping [12].

Outdoor as well as the indoor spaces of healthcare structures are understood as crucial to patients' physical, psychological and social recuperation and wellness [14, 7, 1, 4]: appropriately designed active and passive hospital landscapes enhance patients' interaction with nature and so reduce stress, facilitating interaction with others in ways compatible with and complementary to those found in the urban environment [10, 7].

Gardens and other forms of landscaping come along with many benefits.

1. Psychological: Research shows that high blood pressure and heart activity caused by stress can be decreased if patients are exposed to natural scenes, because such scenes engage them, draw their focus away from themselves and disturbing thoughts, and so contribute to their recovery [1, 15].
2. Physical: Interaction with a natural environment has a positive effect on patients' feeling of well-being, which in turn has a salutary effect on their physical health. In addition to anecdotal evidence, there are theoretical and practical studies illustrating the positive effects of interaction with nature on blood pressure, cholesterol levels and stress-reduction [15, 3, 16, 6, 17]: a study by Robert Ulrich concluded that patients recovering from operations were discharged earlier, took fewer analgesics and were evaluated less negatively by nurses when they had windows in their rooms overlooking nature, compared to patients in similar rooms facing brick walls [14, 10, 11]; and a study of the home environment similarly found that a living context with windows overlooking a natural scene produced "micro-restorative experiences" that enhanced a sense of well-being, as against a context with views of built elements [3].
3. Social: Natural environments in health care facilities contribute to social integration by providing venues for social interaction and support [2].

When creating a garden for a health-care facility, the focus should be on location, accessibility, patients' requirements and preferences, and the design elements to be included [15]. The garden should have opportunities for mobility and exercise, present a choice between social and solitary spaces, and facilitate beneficial distraction and direct or indirect interaction with nature [15].

Outside healthcare spaces come in a variety. They include and are not limited to; landscaped grounds, landscaped setbacks, front porches, entry gardens, courtyards, plazas, roof terraces, edible gardens etc.

A variety of hard landscape features is also instrumental in achieving green gardening and landscaping. Gateways and entrances, parking areas, paths, children's' gardens, dining areas, artwork, water (fountains, taps or ponds), site furniture (signage, seating, receptacles) among other provisions.

Planting Design to a larger extent supplements gardening and landscaping. Plants that need a little water after their establishment period and that can tolerate urban environments and climate change should be preferred when planning healthcare gardens. Other types of vegetation of different densities should be used to connect greenways and wildlife corridors; and native vegetation should be mixed with new compatible plants to support both. Local trees are particularly useful because they attract local fauna: the plant species that attract butterflies create an atmosphere of sweetness; while additional functions (fountains or bird fonts, bird feeders, trees suitable for sleeping or nesting) can be used to attract birds that stimulate feelings with the help of their colors and sounds and increase people's mood.

A dark wooded environment may seem depressing, therefore, sunny meadows and generous paths are preferable for a healthcare environment: they help wild flowers to grow and improve the sensory aspects of nature [18]. Seasonally flowering trees, shrubs and perennials change the comforting understanding of the rhythms and cycles of life; and the use of vegetation, which offers contrast and harmony through textures, shapes, colors and layouts, attracts people's attention and concentration. [17]

The large crowns of the trees provide shade in the summer and offer shelter in the winter; they can help change the local climate and lower the air temperature. The trees, whose leaves move in the wind, draw attention to the patterns of flowers, shadows, light and movement, offering a relaxing and meditative experience [2].

Fruit trees can be good for smaller spaces, and offer seasonal attractions. The edible garden is a useful concept, particularly if the produce can be used in the facility's kitchens. Long-term residents will be able to experience the seasonal development of the garden, and patients in day centers will be able to participate in tending the garden at any time of the year; an activities program might focus on food-growing – for example, eating fruit crumble, or painting berries [15]. Planting an orchard also puts a site which is only available for a short time to good use.

However, hazardous or thorny plants, especially in gardens for children or psychiatric patients, should be discouraged. Low shrubs and dense, dark vegetated “walls” that obscure the view should not be planted near sidewalks; instead, these areas should be planted with year-round screens whose appearance is softened by varied deciduous plants and open spaces.

The design for landscaping site should allow for ease of maintenance, for therapeutic as well as physical safety reasons [19]. Shrubs, trees, and flowers may be more difficult to maintain, but they provide the most therapeutic benefits. Suitable fertilizing, selective thinning rather than shearing, and the use of seasonal color are important factors conducive to the characteristics of the garden that users prefer [18]; hand weeding, mulching, companion planting, and the proper spacing of plants will decrease the use of chemical fertilizers. In short, a poorly maintained environment offends their dignity and has a negative effect on the morale of patients.

It adds more meaning that the gardens are designed for ease of maintenance too. This serves to inspire confidence in patients that they are being well taken care of by the staff. Water-efficient, low-maintenance landscaping should be used, with water conservation achieved by managing storm water runoff in the site. Keeping up and using green spaces around hospitals lowers the costs associated with recovery and also contributes positively to patients' survival chances and quality of life during their stay [16]. Healthcare facilities should landscape and improve their existing green spaces, and then restructure their facilities and patient care practices to provide maximal interaction between patients, visitors, staff and these natural environments. Today the requirements of some specific patient groups are being taken into account when planning and designing outdoor hospital spaces [20]; gardens are being designed for various groups of patients, for instance, the blind, deaf, children, victims of accidents or even heart surgery patients.

### **3 Conclusion**

Healthcare planning companies should plan and design healthcare facilities in such a way that they maximize the utilization of day-light rather than artificial light. Improving the quality of air by using an air sterilizer and certain species of plants, which absorb pollutants is of great significance. Recycling of waste products whenever possible, implementing a proper waste disposal system, use of sustainable materials for construction and avoiding the use of products, which are harmful are essential. Gardens and parks provide aesthetic

beauty, increase patient delight and enhance their well-being thereby helping them feel better faster. Implementing various tools like lean management and six sigma would help in reducing waste. Hospitals prefer purchasing products which are environmental friendly and safe. Thus, the hospital planning companies need to consider the above factors while designing a green hospital and also try to implement it wherever possible.

Although this concept of design of healthcare buildings and structures by green standards comes with significant advantages, not so very many healthcare institutions have embraced it. Lack of awareness, infrastructure, knowledge and proper recycling facilities disadvantage these vital initiatives. Thus, healthcare designers, governments and other stakeholders should emphasize more on planning and building green healthcare structures and find out ways in which this structures can be best implemented to boost healthy environment and better patient outcomes.

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