How Sustainability in Healthcare Sector Challenges Guidelines and Code Development: A Framework for Design of Sustainable Hospital Buildings

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Abstract It is nowadays an accepted fact that built environment is one of the major anthropogenic exploiters of nature as building consume a great amount of resources in the form of energy, materials and water which ultimately causes GHG emissions, resource depletion and waste generation. The concept of sustainability in building sector has not only put forth a challenge for builders but also the governing bodies that deals with the development of codes, guidelines and building standards. There is now a need to accrue all these standards and technology at one place in a framework which may help as a reference approach to design a wholly sustainable building. This study is based on review of literature where data from published articles, books and official websites of code developing authorities has been collected and investigated particular to the design of sustainable healthcare facilities. The output of this study is a comprehensive yet simple framework for the design of wholly sustainable hospital building which covers all aspects of sustainability and it may give designers and learners a portrayal of the process of designing a sustainable hospital building. This research aggregates all the available standards and guidelines for green and sustainable building design which is a good addition to literature and serve as compact reference for designers/constructors who are willing to adopt sustainable design and construction.

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1 Introduction

The climate change and environmental impacts of human activities has become a heated debate at national and international forums (Bigelow and Zhang 2018; Chan 2018; United Nation Environment 2007; Hussain et al. 2018). The most important of all environmental concerns is to dispense the energy demand at global scale (Armendariz-Lopez et al. 2018). Buildings are one of the top environmental exploiters (Maslesa et al. 2018) because of consuming 17% global fresh water, 40% material and energy and 25% of total wood harvest per year (Boudhankar 2017). The consumption of resources and generation of waste is associated to each life cycle stage of building from its construction, operation and demolition. Possibly the best solution to conserve resources and decrease harmful environmental impact is '*sustainability*' which is a science, and a way of thinking and living. The idea of sustainable or green building has gained popularity in recent years. The degree of ecological balance maintained by the building classify it as green or sustainable. However, some literature treats these terms as synonymous. The difference between conventional and green or sustainable buildings is the financial, social and environmental benefits achieved by resource conservation and pollution reduction during building construction and operation phases (Boudhankar 2017).

Environmental impacts attributed to buildings also depend on the type of service provided by these structures. For instance, energy consumption of commercial buildings is higher than that of residential buildings and similarly production of waste and pollution by buildings also varies by their types. Healthcare buildings are considered among the highest resource consuming and waste generating structures (Energy 2010; Administration 2015), and produce significant hazardous and non-hazardous wastes (Pasqualini Blass et al. 2017). It has also been observed in developing countries that healthcare sector is confronting major challenges of cost, poor service quality, limited resources and crucial policies by government (Pasqualini Blass et al. 2017). Therefore, the reduction of hospital building resource consumption and waste generation must be catered at early design stage. But it is not simple as with ever advancing medical technologies and requirements of communities and societies, hospital designs need to support the concept of social, economic and environmental sustainability (Vittori 2013). ASHRAE defines green or sustainable hospital design according to minimization of harmful effects of building on surrounding nature, resources and processes. This means human activities should go hand in hand with nature and natural processes instead of crippling the planet's habitability (ASHRAE 2006).

The new wave of sustainable construction practice started in the 21st century as a challenge for industrialists and policy makers. It required the invention of new technologies, materials, policies and guidelines. Leaders of building industry were fully acquainted with the importance of sustainability in this sector and efforts were made to practically adopt it. Ratings systems such as US Green Building Council's Leadership in Energy and Environmental Design (LEED) emerged to measure the impact of buildings on sustainability. However, the healthcare industry did not attain focus in the early developments but since recently this sector is point of convergence of rating systems and specialized systems have been developed to exclusively deal with healthcare sustainability. One such initiative is the Green Guide for Health Care (Green Guide), a project of the Center for Maximum Potential Building Systems and Health Care Without Harm, which developed and pilot tested a range of sustainable building strategies unique to healthcare.

The architectural design and planning of healthcare facilities was influenced greatly by social, economic and technological advancements (Olenderek and Borowczyk 2016). A variety of research has been done on sustainable architecture, planning and design of hospital buildings which not only focuses on construction but operation and maintenance phases as well. For example, possibilities of floor-plan (Shekhawat 2017), gratuity of evidence-based healthcare design (Verderber et al. 2014), environment and behavior interest in healthcare design (Zhou 2014), contemplative architecture (Bermudez et al. 2017), sense of home (Eijkelenboom et al. 2017), influence of public opinion on architecture (Bianco 2018) implementation of healthcare internet of things, services, and people (HIoTSP) framework using wearable sensor technology (Khowaja et al. 2018), Cyber-Healthcare framework and its implementation (Bagula et al. 2018), variable acoustics within a big range (Cairoli 2018) healthcare distributed services promoting openness, interoperability, reusability and scalability (Calvillo et al. 2013), influence of architectural design features on human experience (Ergan et al. 2018), transforming hospitals to modern hospitals (Haghighathoseini et al. 2018), seismic resilience enhancement of hospitals (Khanmohammadi et al. 2018), technological sustainable subculture (Mavromatidis 2018), and ergonomics in the design process of hospital buildings (Villeneuve et al. 2007) have been investigated. Too many options and pathways leading to sustainability in healthcare are available now including hospital management strategies. This variety, however positively reinforcing for sustainability, has created several decision dilemmas for project teams. The designers and architects must carefully choose among these strategies for an efficient healthcare system. To help them to find a needle in a haystack, this paper presents a framework of design process of a sustainable hospital building. Different standards, building codes, guidelines and published literature have been reviewed to provide a simple methodology for where to begin the design of sustainable hospital, what makes it green and what processes are involved for final sustainability achievement.

2 Methodology

This is a review study of published literature, building design guidelines, codes and standards to provide a simple and elaborate path to engineers, consultants and architects for the design of a sustainable hospital. Stevanovic et al. in their recent article about hospital building sustainability have stated that appropriate methods are required for architects to evaluate hospital sustainability at early design stage because hospitals are complex structures and assessing their sustainability is very challenging (Stevanovic et al. 2017). In this paper a simple framework has been developed to clarify the process of sustainability achievement at design phase of hospital building. Author has studied about internationally recognized organizations which provides building standards, codes, guidelines and certifications either at material level or at building level as a whole. The findings of this study have been presented in two sections below. In first section, a brief introduction of organizations has been provided, which are studied by the author to achieve the goal of this study. The software tools which are very helpful especially in achieving sustainability at design stage have also been discussed. The main finding of this paper is the framework of procedure to design sustainable hospital which explains how things are connected and roles of different organizations to help in the design of sustainable hospital.

3 Building Codes and Guidelines Developers

In this section, a brief introduction of international organizations developing building guidelines, standards and codes applicable universally, have been presented. It also includes some commentary on the famous green building rating systems and software tools used worldwide for efficient and advance architectural, structural and technological design and planning of edifices.

3.1 ASTM International

The American Society for Testing and Materials (ASTM) is an organization which develops and publishes technical standards for a variety of materials, products, services and systems based on the guiding principles of World Trade Organization. These standards are published each year as a set of 80 volumes and broadly categorized into six groups: Standard Specification, Standard Practice Guide, Standard Classification, Terminology Standard and Standard Test Method. These standards include details about specification and testing of all construction materials including metals, rubber, adhesives, plastic, aggregate, cement and many more. ASTM international also provides standards for environmental technology, medical devices and services (ASTM 2019).

3.2 ISO

International Organization for Standardization (ISO) provides world-class specifications for products, services and systems to ensure quality, safety and efficiency. It is instrumental in facilitating international trade. ISO has published 22,215 international standards and related documents, covering almost every industry, from technology, to food, safety to agriculture and healthcare. ISO standards impact everyone, everywhere. ISO also provides standards which are applicable in sustainable construction such as standard for life cycle assessment and environmental product declaration of construction materials (ISO 2019).

3.3 ASHRAE

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) publishes standards for efficient indoor environment. It also promotes research to develop advance and innovative technologies for better indoor environmental technology used for heating, ventilation and air conditioning (ASHRAE 2019).

3.4 ASHE

American Society of Healthcare Engineering (ASHE) is a professional membership group of AHA (American Hospital Association) which provides education, professional development, networking, regulatory guidance and advocacy representation for its members. The members are involved in creating and providing healthcare facilities, and consist of engineers, architects, healthcare facility managers, infection control specialists and many others. ASHE membership is diverse with a common goal: to create and maintain a safe healing environment along with optimizing healthcare facilities (AHA 2019).

3.5 ANSI

American National Standards Institute (ANSI) is a nonprofit organization which represents USA in ISO to create universally recognized and accepted guidelines in almost every industry. It promotes conformity standards to ensure that all manufacturers produce compatible products with same standards and scale to make it easy for consumers internationally. ANSI has brought conformity to all industries worldwide even including safety signage which remains everywhere in the world (ANSI 2019).

3.6 EPA

US Environmental Protection Agency (EPA) strives for reservation and protection of environment to improve human health by indulging in research associated to pollution, its impacts and management. It provides regulations for the manufacturing, distribution and processing of various chemicals and pollutants. It also determines tolerance levels of chemical and other pollutants in food and water for humans and animals. Moreover, it issues regulation for carbon emissions from automobiles, power plants and other climate change contributors (EPA 2019).

3.7 ASME

American Society of Mechanical Engineers (ASME) is a leading international organization which promotes new research and practice in mechanical and multidisciplinary engineering and develops codes, guidelines, standards and conformity assessment programs (ASME 2019).

3.8 FGI

Facility Guidelines Institute (FGI) is a nonprofit organization that works to develop guidance for the planning, design and construction of hospitals, outpatient facilities, residential healthcare and support facilities. For 2018 edition of guidelines, FGI developed three books: a volume for hospitals, a new volume for outpatient facilities and the volume for residential healthcare and support facilities. Each provides basic information on planning, design, construction, commissioning and minimum design requirements for particular facility types. FGI requirements were updated to keep up with changes in healthcare delivery and allow flexibility in design to support development of facilities that will meet the needs of owners and their communities over the long term (FGI 2019).

3.9 GGHH

Global Green and Healthy Hospitals (GGHH) is a network of healthcare facilities, health systems, hospitals and health organizations at global level. This network is indulged in upgrading public and environmental health by reducing healthcare footprint on environment. It connects its members to designers and experts from around the world to educate them and help them achieve their sustainability goals for healthcare facilities (GGHH 2019).

3.10 US VHA

US Department of Veterans Affairs (VA) Health Administration or Veterans Health Administration (VHA) is the largest integrated healthcare system all over the US. VHA has been developing clinical practice guidelines to promote evidence-based best practice in collaboration with Department of Defense (DoD) and foremost expert organizations (GGHH 2019).

3.11 Green Building Rating Systems

Green building rating systems have gained popularity worldwide for the development of green buildings started from UK and US as BREEAM and LEED respectively. Now, many countries even from the developing world have introduced their own rating systems for their local conditions and environment to rate green buildings in terms of site sustainability, energy and water consumption, indoor air quality, material choice, waste reduction and innovation for better environmental performance. The sole purpose of these systems is to reduce environmental impacts of buildings (Shan and Hwang 2018) and overall sustainability of building (Ullah et al. 2019). A number of rating systems from around the world which are very famous and are frequently mentioned in literature are Leadership in Energy and Environmental Design (LEED)—(US), Leadership in Energy and Environmental Design (Canada), Green Star—(Australia), Building Research Environment Assessment Method Consultancy (BREEAM)—(UK), Building Environment Assessment Method (HK-BEAM)—(Hong Kong), Comprehensive Assessment System for Building Environment Efficiency (CASBEE)—(Japan), The Green Globe Rating System—(US), Ecology, Energy Saving, Waste Reduction and Health (EEWH)—(Taiwan), BCA Green Mark—(Singapore) and Australia Greenhouse Building Rating (AGBR) etc. Few ratings systems not only certify buildings in their own countries but also provide green building certification at international level for example LEED, Green Star and BREEAM.

3.12 Software Tools for Green and Sustainable Construction

A huge number of software tools are available to design and simulate different design aspects of green buildings including HVAC system, lightening, day light and glare effects, acoustics, fluid flow dynamics, dynamic thermal simulation, etc. the most popular and frequently mentioned tools in literature and also available worldwide (either free or as educational license to be used by students for research) are Design Builder, Energy Plus, eQuest, Autodesk Revit, Autodesk Insight360, National Energy Audit Tool (NEAT), Autodesk Green Building Studio, Trane Acoustics Program

(TAP), TRANSOL—Solar Thermal Energy, Life Cycle Analysis Tool, SimaPro, Climate Consultant, Athena Calc., Power Calc., etc. SimaPro is the most commonly used software for assessment of sustainability of products and services; its free educational license is available for non-OECD countries.

4 Framework of Sustainable Healthcare Design Process

At its core, a hospital is a construction project and therefore unique in terms of its location, and cultural and environmental conditions. In case of healthcare facilities and hospital construction, not only local conditions impact the design but the demand and variety of required health services also take part in how a hospital system should be designed and planned. Large hospitals are very complex structures and so is meeting their sustainable building requirements. Figure 1 shows a framework for design of sustainable hospital from conceptualization to final life cycle sustainability assessment. It represents the most important facts, codes, guidelines and standards which are employed to make healthcare building sustainable on top of considering modern architecture. This framework categorizes design process into four stages namely selection of critical design aspects, mandatory requirements, performance options and prescriptive options. All these stages of design are interconnected to each other. The first step is selection of building design aspects which are critical to sustainability achievement. Second stage is to fulfill mandatory design requirements or in other words code compliance which should be fulfilled. The next two stages tend to achieve sustainability in design. The detail of each has been mentioned in following sections.

4.1 Selection of Building Design Aspects

To design an efficient building, the main aspects of building must be kept in mind during the design and execution phase. A comprehensive study of literature, green building guidelines, standards and codes was carried out to identify the main features and aspects of an efficient building. If these aspects are designed carefully keeping in mind their environmental impacts, the resulted building will be a green structure. Applying life cycle approach and considering social impact of building will help to achieve a sustainable building. After a comprehensive study of green building guidelines and literature, the basic design aspects have been identified and the mandatory, prescriptive and performance path according to best codes and guidelines have been selected as shown in Fig. 1. These design aspects which are critical for sustainability are Building site, Energy use, Indoor environmental quality, Materials and resources, Airborne emissions, effluent, and pollutant controls, Water supply, and Waste. The

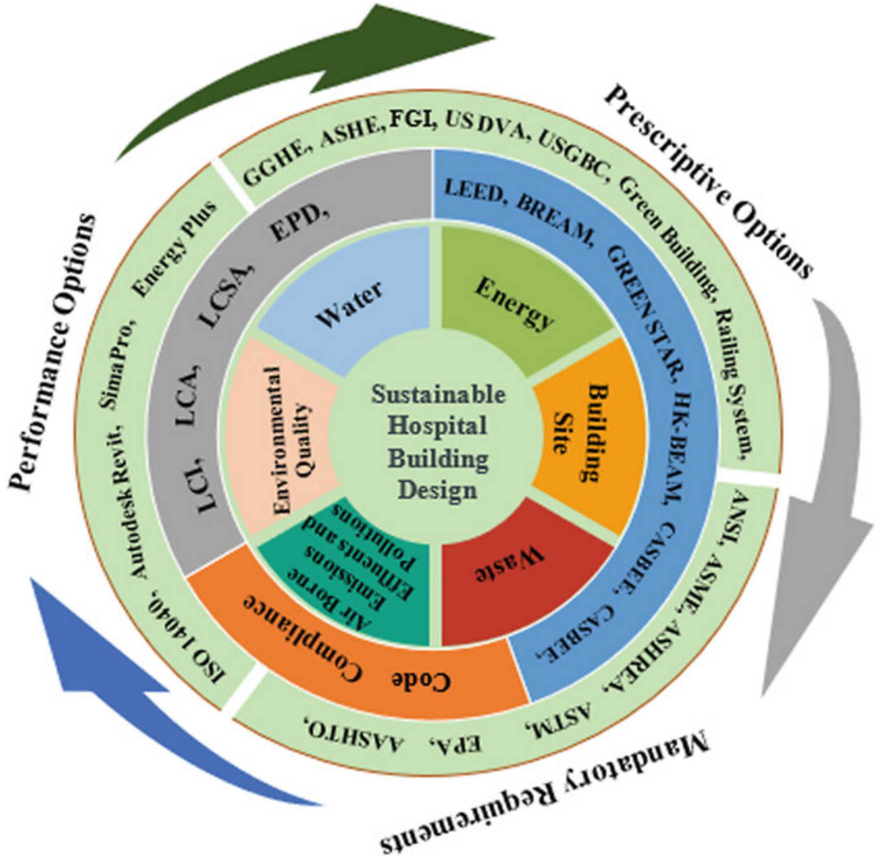

Fig. 1 Framework of sustainable healthcare design procedure

building energy use can be in the form of electricity, thermal and gas. Here electricity use will be applied consistently as an example to elaborate Fig. 1 in further stages of design procedure.

4.2 Mandatory Requirements

Mandatory requirements include all the necessary architectural and structural design, environmental protection and economical aspects of building. Once meeting the mandatory requirements, it needs to go for performance and prescriptive path to make the building sustainable. These guidelines are necessary for code compliance. These codes and guidelines are provided by ASTM, ANSI, ASHRAE, ASME, EPA, IES, and ISO. For example, the most important in any building is the efficient use of electricity which reduces the operational cost of building and environmental impact. The mandatory requirement for electricity use reduction is to provide measurement and verification plan, use of energy efficient electric appliances, efficient HVAC design. For example, ANSI/ASHRAE/IES Standard 90.1: *Energy Standard for Buildings Except Low-Rise Residential Buildings* to should be used for exterior lighting system of building.

4.3 Performance Options

A benchmark for performance of building is established while initiating the building design and these performance goals are achieved by comparison. It allows flexibility and innovation in design to achieve desired performance goals by considering the needs of healthcare organizations. For this purpose, simulation software tools are used to observe building performance under different circumstances. Building energy simulation or energy modeling by using software tools e.g. Energy Plus, eQuest, Autodesk Insight360 etc. can provide heating and cooling load of HVAC, exterior and interior lighting load. Due to flexibility of this option, designer may use innovative techniques developed by researchers and engineers worldwide, for example, Ullah et al. has proved in his study that the use of rat-trap bond in simple brick masonry wall in hot climate areas can reduce the electricity demand up to 60% as compared to conventional brick bond (Ullah et al. 2018). The most important aspect is assessment of building life cycle sustainability which demands a healthcare building to be sustainable economically, socially and environmentally. For an ideal sustainable hospital building, the social sustainability is very important and different guidelines are available to provide best possible healing environment inside the healthcare facilities. Life cycle assessment (LCA) is defined as sum of life cycle costing (LCC), social life cycle assessment (SLCA) and life cycle impact assessment (LCIA). Life cycle assessments are carried out based on standards procedure provided by ISO 14040. Eco-invent provides the largest life cycle inventory database worldwide which can be used to calculate LCA by software tools e.g. SimaPro, Open LCA, GaBi etc.

4.4 Prescriptive Options

The objective of this path is similar to performance path but instead of finding out ways to achieve desired performance goals, already established prescriptive measures are used to reach same design objectives. This style has lesser flexibility as designer has to comply with specific prescribed options. Organizations such as GGHH, ISO, ASHE, ASHRAE, US DVA, FGI and green building rating systems provide guidelines and techniques to achieve sustainability in healthcare sector. For example, ASHRAE provides roofing guidelines that include insulation and the solar reflectance index (SRI) of roofing material which will reduce the requirement of building energy. ISO: 14025 is environmental product declaration guideline to compare and choose greener and environmentally friendly product. Green building rating systems e.g. LEED, CASBEE, BREEAM, HK-BEAM etc. provide specific guidelines and a path to achieve green building certification.

5 Conclusions

Healthcare facilities have significant resource consumption and waste generation potential. Health service is one of the basic human needs and at the time of providing a better healthcare to human beings, robustness of natural environment should not be compromised. In this paper, the importance of sustainability in healthcare services has been emphasized and a framework has been provided to demonstrate the sustainable hospital design process. There are not only international but also national green building standards, guidelines and rating systems that have been developed worldwide. Besides green building rating system, certain software tools have also been developed to help designers to design sustainably and visualize the performance of building prior to its actual construction in the form of building simulation which provides a pretty good idea of how building will perform during its operational life. The framework provided in this study begins with the selection of building design aspects which are crucial to sustainability. A huge number of buildings codes, standards and guidelines required to comply with where some fundamental standards and specifications are mandatory and must be conformed in the design. The sustainability performance requisite of healthcare building is achieved by performance and prescriptive design options, and life cycle sustainability assessment which includes assessment of buildings impact on economy, society and environment. To achieve sustainability at global scale, it is suggested that the choice of builder/owner to go green or construct conventional building should be demoted by development of distinctive and comprehensive sustainable building codes, standard and guidelines available as a single set of guidelines to follow and construct sustainable structure only.

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