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Architecture and Sustainability: Integrating Health Performance Indicators in Sustainable Architecture — A Comprehensive Study on Enhancing Human Well-Being and Environmental Efficiency

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Abstract: The phrase "health and well-being" includes various aspects such as social, psychological, and physical factors. The way we design, construct, and operate buildings greatly affects people and their experiences. Costs associated with employees make up a significant part of expenses, and enhancing the well-being of those in the workplace can boost productivity. Optimizing buildings offers benefits, but it also presents challenges, particularly regarding energy consumption, material usage, and environmental impact. Eco-friendly buildings provide a solution to balance our comfort with the requirements of the environment. This article examines the impact of buildings on people and the environment, suggesting a framework for a "health performance indicator" to improve the research and practice of sustainable buildings, ultimately aiming to enhance both human and ecological well-being.

Keywords: Sustainability; Sustainable architecture; Water and energy efficiency

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1. Introduction

Human beings spend nearly 90% of their time in buildings, which largely impacts human health, happiness, performance, and safety [1]. Buildings consume a lot of energy and materials, have an impact on the environment, and are expensive to maintain. Thus, sustainable construction becomes an effective way to improve human lives while also protecting the environment. It has the potential to contribute to the achievement of global sustainability goals such as climate change, the development of sustainable and prosperous communities, and the promotion of economic growth. The advantages of sustainable construction are environmental, social, and economic [2]. As a result, it is critical to construct and renovate sustainably. This article will examine the beneficial and detrimental impacts of buildings on individuals and the environment, and we will provide a framework for establishing direct, objective, and leading "health performance indicators" for future studies on buildings and health [3].

2. Sustainable communities and sites

A construction project has a significant impact on the local community and the site itself [4]. There is a significant likelihood of loss of diversity, and cultural value, among other economic and use-values due to the construction of the proposed commercial development. The project must also meet sustainable community standards and reduce the rate of carbon emissions. With more than 55% of the global population living in cities, the risk of higher carbon emissions remains high [5]. The development will have to provide occupants with a place to relax, connect with nature, and take a break from the artificial world. Designing a mini-park or a futuristic garden will be ideal here given the limited space. Primarily, creating sustainable communities will require:

(1) Emphasis on achieving Zero-Net carbon operations at the site and limiting fossil fuel use [6].

(2) Building with low to zero embodied carbon, or carbon sequestering materials, and consideration of embodied carbon at all levels of design and planning, including infrastructure and building reuse, site selection and landscape, and interior fittings and finishes

Therefore, the contractor will have to ensure that the site details and specifications have the least adverse effects on the environment, people, and communities. To achieve these goals, the site layout should meet the requirements set out by Leadership in Energy and Environmental Design (LEED) for sustainable sites such as pollution prevention, site assessment, protection or restoration of habitat, rainwater management, heat island reduction, creation of open spaces, and light pollution reduction [7]. To achieve these, it will require:

(1) Protecting disturbed areas during site preparation, such that the construction team must recognize the value of trees and incorporate that in the project specs.

(2) Controlling soil erosion that may result from site disturbances to prevent the pollution of nearby waterways and foul sewers.

(3) Controlling site boundary to limit the project's disturbance area to a smaller footprint to maintain the existing footpaths, bike lanes, and accessible routes along N 12th St, W Norris St, and N Marvine St.

(4) Consider completing landscaping exercises first to reduce site disturbance, reduce the risk of soil erosion, and allow the plants to regenerate as construction continues.

(5) Include fuel usage protocols in the project specs to limit pollution.

3. Water efficiency

The notion of water efficiency is a multi-faceted concept. It refers to "doing more and better with less" by making the most of the available resources, cutting down on resource consumption, and lessening the pollution and environmental effects of using water to produce goods and services at every point of the value chain as well as the provision of water services [8]. The advantages of green buildings for energy and water saving have been extensively researched and acknowledged [9]. We presented a system and metrics for evaluating building health for energy and water saving.

The volume of water on Earth is finite. Thus, it requires efficient use of water resources to serve the growing global population, especially with freshwater for domestic and agricultural use. In urban areas, like the proposed site, the primary water management problem is controlling surface run-offs. In most old cities like Philadelphia, the drainage system combines the sewer system and sanitation where pipes handle both sewer and runoff. Combined sewers may overflow, releasing treated and untreated sewers into rivers when the treatment plants are overwhelmed during rainy seasons. Thus, the proposed building will have to utilize various techniques to harvest rainwater and minimize surface runoff, such as the following.

(1) Vigilant stormwater management is needed to minimize runoff during construction, using retention areas and porous materials for paving to maximize water infiltration. The site infrastructure must hold at least 1.5” of rainwater per Philadelphia Water Department (PWD) regulations.

(2) Encourage green infrastructure within the site such as rain gardens, vegetated roofs, and bioswales. Vegetated roofs have proven highly advantageous for stormwater management, thermal insulation, evaporative cooling in summer, and reducing heat islands in urban areas.

4. Material and resources

Construction materials constitute a significant portion of a building’s carbon dioxide emissions. Therefore, the project specifications must include strategies to reduce embodied carbon emissions from materials like concrete and wood. The first step will involve conducting a Life Cycle Assessment (LCA) of construction materials to determine their carbon footprint across the value chain. That will require working with Athena Sustainable Materials Institute (ASMI) to conduct the materials’ LCA to meet material disclosure under LEED [10]. The building will also follow the American Institute of Steel Construction (AISC) sustainable steel material attributes in the selection of steel used for concrete reinforcement and other construction works. Using innovative timber and timber products and encouraging the supply of wood from suppliers with the least carbon footprint will also reduce the building’s carbon footprint. Since concrete is the primary cause of embodied carbon in buildings, the development shall consider the following.

(1) Substituting cement with other supplementary cementitious materials (SCMs) or using larger aggregate may be applicable to reduce the amount of cement used.

(2) Lightening the weight of slabs using lightweight concrete with high strength or incorporating voids in the concrete using things like proprietary air-filled recycled plastic spheres to reduce the amount of concrete that will be required in the construction project.

(3) Using non-fossil fuel-based SCMs to reduce carbon emissions such as glass pozzolan [11].

(4) Encourage suppliers to use carbon sequestration, where the carbon dioxide released during cement manufacture is captured and injected back into the concrete during mixing.

(5) Designing the building with a vision of material optimization and efficiency.

5. Energy efficiency

In emerging economies, building construction is expected to be a very intensive activity in the coming years. This is mainly due to the increase in population, growing wealth, growing desire for improved lifestyles, and increasing pace of urbanization [12]. The energy demand for space cooling and heating is growing rapidly across the globe. Most of these countries are in tropical and warm climate regions. The prevailing temperatures in these countries make space cooling and heating a necessity.

Energy efficiency remains a significant problem in most buildings today. To ensure that the building will have a high energy efficiency rating, it will need to incorporate the use of reflective glasses to reduce heat gain, solar panels to reduce reliance on fossil fuel for heating and cooling, and utilize materials and systems that will seek to maximize the building’s passive solar gain. For heat gain and loss efficacy, solar control glass will be the best option. The glass allows only sunlight to enter the offices, creating a brighter indoor environment. However, it prevents the passage of sunlight heat by reflecting and largely radiating it, resulting in a cooler environment. It also prevents ultraviolet (UV) rays from entering and reduces exposure to zero, making the building more sustainable.

To maximize the passive solar gain, the building will be designed with full consideration of the direction of the sun and the prevailing wind directions to allow natural cooling and heating of the building spontaneously. The proposed heating, ventilation, and air conditioning (HVAC) system that will be used is the variable refrigerant flow (VRF) and variable refrigerant volume (VRV) [13]. Heat pumps and heat recovery are used in VRF and VRV systems. Heat pump systems can heat or cool a building at any time, making them ideal for open-plan spaces. Heat recovery systems can provide simultaneous heating and cooling to several areas, making them an ideal solution for a building with multiple rooms [14]. **Table 1** shows the R-values, the thermal resistance measure, of different materials.

Table 1. The suggested R-values

R-Values/Name	Dimension (inch)
Spray polyurethane foam	6.6 per inch of thickness
Thermoplastic polyolefin (TPO)	0.24 per inch of thickness
Metal	0.00 per inch of thickness
Built-up roof (BUR) gravel	0.34 per inch of thickness
Extruded polystyrene (XPS) Insulation	5.0 per inch of thickness
Polyisocyanurate (Polyiso)	5.5 per inch of thickness
BUR smooth	0.24 per inch of thickness
Expanded polystyrene (EPS) Insulation	3.85 per inch of thickness
Ethylene propylene diene monomer (EPDM)	0.33 per inch of thickness

6. High-performing exterior cladding

Traditional louvered or Venetian blind systems will be used to allow users or an automated control system to tailor the adjusted angle of blockage based on solar position, daylight availability, glare, or other criteria. Another option is to use between-pane acrylic prismatic panels that are either fixed or used as a system of exterior louvers to block direct sunlight while admitting diffuse daylight. Vertical window panels will be adjusted at least seasonally to block sunlight and prevent color dispersion.

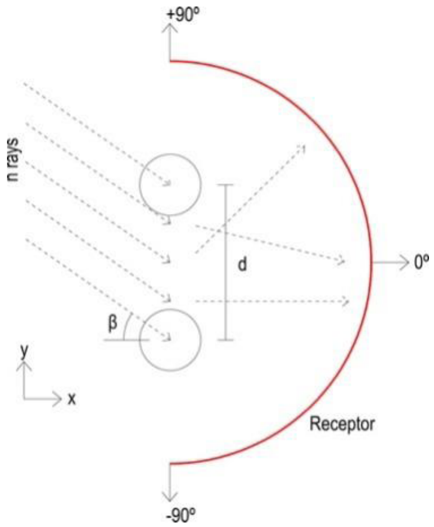

Figure 1. Ray-tracing basic modeling setup: *n* light rays are spread out around two cylinder-shaped louvers that are *d* units apart. Over a half-circle receiver, the scattering features of the screen system were tested at different elevation angles [15].

Table 2. Room and material surface photometric properties

Room surface photometric properties	Reflectance/Transmittance
Wall	0.6 (grey, diffuse)
Ceiling	0.8 (white, diffuse)
Floor	0.3 (grey, diffuse)
Window	0.64 (double panes, transmittance) 0.8 (single pane, transmittance)
Shading material photometric properties	**Overall reflectance and materials**
Rod	0.92 (specular, polished aluminum)
New louver (exterior)	0.92 (specular, polished aluminum)
New louver (interior)	0.92 (specular, polished aluminum)
Venetian blind	0.92 (specular, polished aluminum)

7. Conclusion

Preliminary research reported so far indicates that green buildings have superior measured and perceived results for indoor environmental quality and health status compared to non-green buildings. The design for health is increasingly integral to green buildings, and the need for high-quality health indicators will be essential as researchers assess the efficacy of these programs in comparison to LEED-certified and conventional structures. They are beneficial in developing research aimed at identifying certain building-related qualities in green or other structures that enhance occupant health.

Disclosure statement

The author declares no conflict of interest.

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