

Challenges of implementing biophilic design principles in hospital infrastructure development: A review

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ABSTRACT: The implementation of biophilic design principles and strategies has become a popular and acceptable idea in both developed and developing economies. While studies acknowledge the potential of biophilic design in hospital settings, the implementation of biophilic principles in developing healthcare infrastructure faces numerous challenges that are neither highlighted nor well documented. This study examined important issues that typically limit the use of biophilic features, based on a review of published literature. The study identified regulatory compliance and cost constraints as the main categories of challenges faced in the implementation of biophilic design. The study recommends awareness and engagement of all stakeholders from the design stage to the implementation stage and post occupancy evaluations, as well as financial incentives to encourage the adoption, innovation and development of specialized skills and business ventures in biophilic design and sustainable infrastructure development.

Keywords: Biophilic Design Principles, Biophilic Design Challenges, Hospital Infrastructure, Built Environment, Review

1 INTRODUCTION

The major point of biophilic design in architecture is to create a close relationship with nature in order to improve people's health and productivity. These guidelines promote peaceful coexistence with nature through the integration of natural elements into the built environment. The fundamental concepts of biophilic design are as follows: visible and physical (Bahador 2023), indoor-outdoor relationship with the natural environment (Chawla 2012), organic forms and designs (Djouad 2021), natural light and natural ventilation (Gillis and Gatersleben 2015), natural and locally sourced building materials (Jaheen and El-Darwish 2021), use of water elements (Alam 2023), as well as multisensory and cognitive functional spaces (Peters and D'Penna 2020). Applying these biophilic design concepts, architects and designers may create environments that enhance human health, well-being, and productivity while simultaneously forging a robust and long-lasting bond with the natural world.

According to Untaru, Ariza-Montes, Kim, and Han (2022), the application of biophilic design principles in healthcare environments has been shown to improve recovery outcomes, lower stress levels, and promote well-being. Research indicates that having a view of the outdoors and incorporating biophilic patterns into healthcare settings, directly improves people's well-being, reduces discomfort, and speeds up their recuperation from disease and operation procedures. Research indicates that biophilic elements, such natural light,

vegetation, and access to nature, can help patients heal more quickly, experience less mental stress, tolerate pain better, and spend less time in the hospital (Untaru 2023). As a result, biophilic design is becoming more and more important in the healthcare industry, because it is seen to humanize healthcare spaces and thus enhancing emotional well-being and improving the overall experience for both patients and healthcare professionals (Kellert 2015). Totaforti (2018), further explained that well-known medical facilities that demonstrate the successful application of biophilic design in hospitals have improved patient outcomes and experiences as a result.

Studies have shown that using biophilic design principles in hospital infrastructure can help solve a variety of problems and improve the overall resilience of healthcare settings. Biophilic design architecture makes a significant contribution to the design of resilient infrastructure for hospitals by incorporating natural elements that improve the well-being of patients, staff, and visitors while also increasing the resilience of healthcare facilities. Biophilic design architecture is essential for building resilient hospital infrastructure in the following domains: enhancing healing environments (Purani and Kumar 2018), improving resilience to disasters (Sunindijo *et al.* 2019), promoting sustainable practices (Achour *et al.* 2014), fostering collaboration and innovation (Guzzo *et al.* 2022) and addressing stakeholder needs (Bergerød *et al.* 2022).

1.1 *Aim and objectives*

Despite the fact that previous studies acknowledge the potential of biophilic design in hospital settings, the implementation of biophilic principles in healthcare infrastructure is faced with many challenges that are neither highlighted nor well documented. Therefore, there is limited knowledge about the challenges of implementing biophilic design principles in hospital infrastructure development. This study aimed at bridging this knowledge gap, drawing insights from an extensive review of published literature, dissecting the hurdles and limitations inherent in applying biophilic design principles within hospital environments, focusing on three main objectives. Firstly, delineating the many challenges encountered while implementing biophilic design strategies in hospitals, as documented in existing scholarly works. Secondly, categorizing these difficulties and identifying recurring themes and patterns in various sources; and lastly, to spotlight the primary barriers observed in executing biophilic design strategies in hospital contexts.

Through achieving the said objectives, the study contributes not only in addressing the theoretical knowledge gap in biophilic design principles and hospital infrastructure, but also offers valuable insights that can inform decision-making processes and facilitate the formulation of standards and regulations to promote sustainability and resilience in hospital infrastructure development.

The study encourages innovation and the development of specialized skills and business ventures in biophilic design and sustainable infrastructure by pushing architects, engineers, contractors, and other construction professionals to devise design solutions and develop construction strategies that address implementation challenges. The research provides more support for the application of biophilic design, thereby advancing sustainability—a critical component for developing nations confronting environmental concerns. Greener urban development can be promoted and energy consumption can be decreased by implementing biophilic concepts in improved hospital designs.

With practical insights for all parties involved, the study provides a thorough understanding of the challenges to implementing biophilic design in hospitals. It also offers an educative platform for decision-makers on the advantages and difficulties of biophilic design, resulting in laws and incentives that encourage the construction of sustainable healthcare infrastructure. The study is also a useful resource for academic institutions to use as teaching material for improving courses on sustainable development, architecture, and healthcare administration.

2 METHODOLOGY

The research is a literature review that made use of qualitative research methodology. The conduct the study, five steps were used. Step one involved identification of the research problem and aim of the study. The second step was the development of research objectives to achieve the aim of the study. Step three involved gathering of data from secondary sources such as published literature in Scopus, Science Direct, and Google Scholar, to identify and categorize the different causes of challenges in implementing biophilic design in hospitals, using the following keywords: biophilic building principles, hospital design, implementation challenges, causes and limitations. The fourth step involved gathering of 105 documents published between 2007 and 2024 that were selected based on a review of their topics and abstracts that contain related thoughts to the purpose of the study. The fifth step involved the selection of 30 of the documents that eventually constitute the sample size of literatures reviewed and data collected from them, after a careful scrutiny of their text. The data was content analysed by theme analysis using descriptive approach. The results were presented in themes with a table and a diagram to facilitate understanding.

3 RESULTS AND DISCUSSIONS

Implementing biophilic design in architecture can be challenging due to various building design constraints. These challenges can hinder the seamless integration of natural elements into the built environments, impacting the effectiveness of biophilic design principles. To compound these challenges, there is limited knowledge on the causes of the difficulties involved in using biophilic design concepts in hospital environments. There is also no clear understanding and documentation of the number of causing factors and their categories, associated to the planning, design, construction and operation of hospitals. To bridge this knowledge gap, 15 different causes of challenges to biophilic design in hospitals were discovered as presented in Table 1.

Table 1. Causes of challenges in the implementation of biophilic design strategies in hospitals arranged according to rating, based on the number of publications identifying the causative factor.

No.	Causative factor	No. of articles	Rating	Sources
1.	Building Codes, Standards, Guidelines and Regulatory Compliance	8	1st	10,14,17,19,33,37,38,42
2.	Cost Constraints including initial, operational, return on investment, cost benefit analysis and maintenance costs	7	2nd	16, 25, 26,27, 28, 29,39
3.	Maintenance and operational requirements, including plan care demands, operational efficiency, indoor air quality and environment	6	3rd	14,16,35,36,37,40
4.	User preferences	5	4th	9,15,21,23,41
5.	Space limitation	2	5th	10,16
6.	Adaptation to Local and Urban Contextual issues	2	5th	12
7.	Infection Control Measures	2	5th	31,34
8.	Structural limitations	1	6th	16
9.	Technical expertise	1	6th	17
10.	Climatic adaptations	1	6th	12
11.	Symbolism and meaning	1	6th	23
12.	Spiritual and ritualistic practices	1	6th	23
13.	Historical Context	1	6th	22
14.	Perception of nature	1	6th	20
15.	Functional Requirements	1	6th	20

From the data displayed in Table 1, the main categories of challenges were the building codes and costs contains, followed by maintenance requirements and user preferences issues faced in implementation of biophilic design in hospitals, especially in developing economies. The causes of the challenges identified in implementing biophilic design strategies in hospitals were categorised under seven main groupings as illustrated in Figure 1.



Figure 1. Categories of causes of challenges in implementation of biophilic design strategies in hospitals.

The seven categories of the causes of the challenges of implementing biophilic design strategies in hospital developments are examined as follows:

3.1 *Building design and considerations*

Incorporating biophilic design elements, such as green roofs, natural materials, and water features, into a building will result in higher construction and maintenance costs, which will present financial challenges for the project's implementation. The integration of large-scale biophilic components, such as abundant vegetation or indoor gardens, may be restricted in building designs with limited space, hence restricting the possibility to create immersive natural environments. Due to structural limitations and retrofitting difficulties, existing building structures might not be suitable for implementing biophilic features, such as natural light optimization, ventilation systems, or living walls. It can be difficult to maintain biophilic elements like living walls, water features, and vegetation over time, especially in commercial buildings or high-traffic areas (Guzzo *et al.* 2022). According to El-Baghdadi and Desha (2017), the application of some biophilic design components may be hampered by building rules and laws, particularly in urban settings where zoning limits and environmental requirements must be taken into account. It might be difficult to find the specific knowledge and technical expertise experience needed to design and execute biophilic features in fields like landscape architecture, ecological design, and sustainable building techniques (Mahrous *et al.* 2022). Striking a balance between biophilic design components, user preferences, and functional requirements can also be challenging since different people may have different views on how to integrate nature, which could affect the design's overall success (El-Bannany *et al.* 2022). The viability of some biophilic aspects is also determined by local climates and ecosystems, since certain natural features might not flourish or be viable in particular climatic conditions (Parsaee *et al.* 2020).

3.2 *Cultural considerations*

Different cultures interpret colours, patterns, and natural elements metaphorically. Misunderstandings or resistance may occur when biophilic design elements go against cultural norms or beliefs. Because cultural aesthetics and design traditions vary by region, biophilic design needs to cater to local tastes in order to be well-received. When working with particular cultures, it can be challenging to find a balance between spiritual considerations and design aesthetics because of their ritualistic or spiritual connections to nature, which have an impact on how biophilic design is viewed and used (Tomasso *et al.* 2021). The influence of historical and cultural legacies on design decisions is profound. When integrating biophilic elements, a location's cultural legacy must be honoured and reflected, which necessitates significant thought and understanding. In order to successfully integrate biophilic design within the specific cultural and environmental context, considerations such as climate, location, and cultural norms must be made (O'Sullivan *et al.* 2023). Effective design must include local communities in order to understand the needs, customs, and values of the community. Socioeconomic disparity and resource availability impact the viability and adoption of biophilic design, making it challenging to maintain cultural values while ensuring affordability and inclusivity (Ferreira *et al.* 2020). Since diverse cultures have differing viewpoints on nature, the wilderness, and urban green spaces, it is challenging to apply biophilic design to create inclusive and culturally sensitive ecosystems (Barbiero and Berto 2021).

3.3 *Economic considerations*

One of the greatest challenges is the cost of implementing biophilic design components in hospitals. The initial cost of adding natural elements like plants, water features, and natural materials can put healthcare facilities in a tough financial situation. Funding biophilic design projects may have to compete with other important medical expenses due to the rising cost of hospital operations. Finding a balance between healthcare facilities' overall financial constraints and the costs associated with integrating biophilic design can be challenging (Dion and Evans 2022). It might be difficult to prove the financial advantages of biophilic design in healthcare settings. Hospital administrators may need to provide proof of the financial gains from biophilic design, such as better patient outcomes, lower operating expenses, and higher employee satisfaction (Shin *et al.* 2022). Dion and Evans (2023) stated that, given competing demands for healthcare, integrating features inspired by nature necessitates careful resource allocation and prioritisation. Water components, green roofs, and living walls are examples of biophilic design elements that need constant upkeep and attention. Hospital finances and resources may be strained by the ongoing operating expenses related to preserving biophilic features (Gola *et al.* 2020). It is imperative to carry out a comprehensive cost-benefit analysis prior to introducing biophilic design in hospitals. While assessing the financial effects, possible savings, and advantages of biophilic design projects can be difficult, doing so is essential for making decisions (Almusaed *et al.* 2022).

3.4 *Regulatory compliance*

To safeguard patients, hospitals are required to adhere to stringent infection control protocols. According to Tekin, Corcoran, and Gutiérrez (2022), biophilic materials, like plants and water features, have the potential to harbour bacteria and pathogens, making infection prevention and hygiene more difficult. Hospital design must adhere to healthcare regulations and construction norms, which may restrict biophilic features like big windows or green walls because of fire safety regulations, privacy concerns, or structural integrity issues (Mahrous *et al.* 2022). In order to prevent maintenance problems or safety hazards, biophilic aspects must be carefully studied. Patient and staff safety is of the utmost importance (Mollazadeh and Zhu 2021). The incorporation of biophilic characteristics may be impacted

by noncompliance with healthcare standards, especially with regard to cleaning and maintenance (Untaru *et al.* 2022). Finding a balance between the therapeutic benefits of biophilic design and the functional needs of healthcare facilities like patient care and workflow efficiency, can be challenging. Ensuring accessibility for patients with disabilities or mobility challenges is crucial, as some biophilic features may not comply with accessibility criteria (Zhao *et al.* 2022).

3.5 *Operational issues*

In order to remain healthy and dynamic, biophilic design elements such as living walls, vegetation, and water features need to be maintained on a regular basis. Hospitals must set aside money for continuing, labour and money, intensive plant maintenance such as pruning, watering, and pest control. Understanding horticulture is crucial for integrating greenery into medical settings, guaranteeing plant development, controlling seasonal changes, and preserving the health of indoor plants (Ebekoziem *et al.* 2021). Hospitals prioritize interior air quality in order to keep visitors, employees, and patients in a healthy environment. Because adding biophilic elements might alter humidity, air circulation, and allergens, it is essential to monitor and manage them appropriately (Jandali and Sweis 2018). Hospitals must implement strict infection control protocols in order to stop the spread of infections. Biophilic elements, especially water features and plants, might make microbiological control and cleaning more difficult, necessitating the use of strict infection control methods (Gola *et al.* 2019). It's critical to strike a balance between the aesthetic advantages of biophilic design and operational efficiency. To guarantee that biophilic elements do not compromise patient safety, interfere with workflow, or prevent access to medical equipment, careful design and integration are required. Respecting the legal requirements for infection control, indoor air quality, and facility upkeep is essential. Observing these guidelines combines biophilic elements with patient safety (Yousefli *et al.* 2017).

3.6 *Spatial constraints*

Hospitals often lack the space required for biophilic features like plants, water features, and natural materials, especially when located in urban areas. The implementation of biophilic design concepts, which involve gardens, plants, and outdoor areas, is impeded by spatial limits (Untaru *et al.* 2022). The integration of biophilic features in urban hospitals can be hindered by restricted access to green spaces and natural surroundings (Tekin *et al.* 2022). Also, Urban hospitals' emphasis on interior spaces often restricts options for biophilic elements like views of flora, outdoor access, or natural light, affecting indoor biophilic design (Zhao *et al.* 2022). Careful design is necessary to ensure that biophilic features are accessible to patients, staff, and visitors in hospitals with limited space (Cabanek *et al.* 2020). It is difficult to incorporate biophilic elements while achieving operational goals in hospitals since they have special functional needs that must be met in small areas (Barbiero *et al.* 2021). Due to the potential negative effects of space limitations on patient experiences and health, innovative approaches to creating healing spaces with biophilic elements in compact spaces are required (Untaru 2023).

3.7 *Stakeholders' resistance*

Hospital managers, staff, and patients are examples of stakeholders who may not fully understand the concepts of biophilic design. Another potential source of resistance is a lack of understanding of the benefits of incorporating nature-inspired features into healthcare environments. The application of biophilic design may result in perceived disruptions to current hospital operations, which may be the source of resistance. When changes are seen as a threat to established procedures and workflows, stakeholders may oppose them. Hospitals

may need to make additional investments in order to implement nature-inspired aspects, and stakeholders may be reluctant to commit funds in the absence of convincing cost-benefit analyses (Edwards 2023). Diverse aesthetic preferences among stakeholders can also create resistance to nature-inspired design elements (Prugsiganont and Waroonkun 2021). Operational concerns, such as higher maintenance needs for vegetation and infection control issues, may further oppose biophilic design (Kilaru *et al.* 2022). Stakeholders may also resist biophilic design if it contradicts existing rules or conventions in healthcare facilities. Resistance is often exacerbated by inadequate stakeholder participation and insufficient information about the benefits of biophilic design. Effective communication strategies are essential to address concerns and gain support for biophilic initiatives (Shepley *et al.* 2022).

4 CONCLUSION AND RECOMMENDATIONS

This review identified and categorized the different causes of difficulties and limitations involved in using biophilic design concepts in hospital environments. A number of causes of the challenges in implementing biophilic design strategies in hospitals were identified from published literature. The review identified regulatory compliance and cost constraints as the main categories of challenges followed by maintenance requirements and user preferences issues faced in implementing biophilic design in hospitals, especially in developing economies. In addition, seven categories of the causes of the challenges in implementing biophilic design strategies in hospitals were discovered and examined. They include: building design considerations, cultural considerations, economic considerations, regulatory compliance, operational issues, spatial constraints and stakeholders' resistance.

To address the challenges of implementing biophilic design principles in hospital infrastructure development, the study recommends the following: First, efforts should be made by building professionals to create awareness and engagement of all stakeholders from the design stage to the implementation and post occupancy evaluations stages. Second, government agencies managing innovative discoveries should provide financial incentives for incorporating biophilic features and for encouraging innovation and development of specialized skills and business ventures in biophilic design and sustainable infrastructure. These efforts are likely to push professionals more, to devise design solutions and develop construction strategies that address implementation challenges.

Through achieving the objectives of this study, the paper contributes to advancing knowledge by providing more illumination towards understanding the causes of the challenges associated with biophilic design in healthcare settings. Moreover, it has provided useful insights that can inform decision-making processes and facilitate the development of standards and regulations to promote sustainability and resilience in hospital building design. The study recognizes that literature review has limitations, especially in the fact that it uses secondary data. However, this does not negate the contributions of the study. In order to overcome this obstacle and encourage the incorporation of biophilic design concepts in hospital environments, the review concludes by highlighting the importance of further research on interdisciplinary cooperation, creative solutions, and evidence-based tactics on the implementation of biophilic design strategies in hospital settings. The study further recommends that research should be carried out to identify and analyse the causes of limitations in application of biophilic design from a selected sample of hospitals within one of the growing economies.

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