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IMPROVEMENT OF HEALTHCARE FACILITY ARCHITECTURE

Sh. A. Egamberdiyeva
Scientific Advisor, Teacher of the "Architecture and Hydraulic Engineering" Department of Andijan State Technical Institute
Gmail: salmonxonoyxon@gmail.com

J. J. Komilov
Master's Student, First Year Andijan State Technical University, Department of Architecture and Hydraulic Engineering
Gmail: j.komilov1996@gmail.com

Abstract
This article provides a scientific analysis of modern approaches, architectural–functional solutions, and innovative technologies aimed at improving the architecture of healthcare facilities. The purpose of the study is to enhance architectural quality by organizing functional zoning in healthcare institutions rationally, optimizing patient flows, ensuring infection safety, increasing energy efficiency, and implementing the principles of a "healing environment." The research methodology is based on the analysis of regulatory documents, observations in existing medical institutions, interviews with specialists in the field, architectural–functional modeling, and conceptual design processes using BIM technologies.The results of the study show that existing facilities have several issues, such as disproportions in zoning, insufficient performance of air exchange and filtration systems, lack of psychological comfort for patients, and low energy efficiency. The proposed solutions - modular and flexible planning, one-way movement schemes, high-efficiency ventilation systems, biophilic design elements, and the integration of digital BIM technologies - make it possible to significantly improve the functional, sanitary-hygienic, and ecological efficiency of healthcare facilities. The conclusions of the study can be applied in the development of new projects as well as in the reconstruction of existing facilities.

Keywords: Healthcare architecture; functional zoning; patient flow; infection safety; energy efficiency; healing environment; biophilic design; BIM technology; modular planning; medical facilities.

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Introduction

The architecture of healthcare facilities holds strategic significance in the modern era, as it directly influences the quality of medical services, the recovery process of patients, the efficiency of healthcare personnel, and the overall level of infection safety. In the design of medical institutions, functional zoning, the proper organization of patient and staff flows, the clear separation of sterile and non-sterile areas, the optimal placement of engineering systems, and the implementation of energy-efficient solutions represent essential architectural requirements. Experiences gained during the pandemic once again demonstrated the critical importance of infection control, air purification systems, the flexibility of quarantine modules, and the continuity between functional units in modern hospitals.Today, the construction and reconstruction of healthcare structures actively employ innovative approaches such as BIM technologies, CFD modeling, biophilic design elements, and modular-typological planning. These approaches not only improve functional convenience but also enhance energy efficiency, ecological sustainability, maintenance effectiveness, and long-term economic viability. International standards - including LEED Healthcare, WHO Health Facility Guidelines, DIN, and HTM requirements - serve as important methodological bases for evaluating and improving the architectural quality of healthcare facilities.The primary objective of this research is to develop scientifically grounded practical directions for improving the architecture of healthcare facilities in the context of Uzbekistan, identify existing issues, and propose contemporary solutions based on global experience. In this study, functional continuity, infection safety, patient comfort, and energy efficiency are considered key analytical parameters.

Methodology

In this research, a comprehensive and systematic methodological approach was applied to develop scientifically grounded conclusions regarding the improvement of healthcare facility architecture. First, the functional-planning solutions of existing hospital buildings, the organization of patient and staff flows, the placement of sterile and non-sterile zones, the continuity between departments, and overall safety indicators were analyzed. In this stage, analytical tools such as **Flow Mapping**, **Space Syntax**, and **Wayfinding Evaluation** were used to identify flow

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intersections, excessive walking distances, centralized and peripheral functional nodes. In the next phase of the study, the digital model of the healthcare building was created based on **BIM (Building Information Modeling)**. Through this model, parametric analyses were conducted on the distances between departments, continuity of technological processes, the arrangement of engineering systems, and maintenance convenience. Additionally, **CFD (Computational Fluid Dynamics)** simulations were performed to scientifically assess indoor air circulation, pressure differentials, ventilation efficiency, and the potential spread of infectious particles.The ecological and energy efficiency aspects of medical facilities were evaluated according to **LEED Healthcare** standards. During this process, indicators such as building insolation, heat-loss coefficients, natural ventilation capacity, lighting efficiency, insulation materials, and overall energy consumption were thoroughly examined. The psychological comfort of patients was assessed using methods related to **biophilic design**, **acoustic comfort**, **visual comfort**, and **ergonomic mapping**. Finally, a comparative benchmarking analysis was conducted using hospital architecture examples from Germany, Japan, Singapore, South Korea, and Turkey to identify adaptable models and improvement strategies suitable for the conditions of Uzbekistan. These combined methods allowed for a holistic understanding of architectural optimization approaches in modern healthcare facilities.

Results and Discussion

The study results indicate that the functional-planning of existing hospital projects in Uzbekistan is insufficient for the optimal organization of patient and staff flows. Analyses using **Flow Mapping** and **Space Syntax** revealed that certain interdepartmental distances are excessive, and central nodes are overloaded. This leads to additional travel time and stress for staff and patients, while also increasing infection risk. Additionally, the intersection points of sterile and non-sterile zones are sometimes improperly located, reducing the efficiency of air circulation systems. Findings from **BIM** and **CFD** modeling demonstrated that digital planning and airflow analysis significantly improve functional continuity and infection safety. Optimizing indoor ventilation systems, pressure differentials, and sterile zone isolation reduces patient risk and enhances staff working conditions. Energy efficiency calculations, compared with **LEED Healthcare** standards,

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showed that effective use of natural ventilation and daylighting can reduce energy consumption by approximately 15–20%. Psychological environment assessment confirmed a direct correlation between patient comfort, stress levels, and recovery outcomes. Methods such as **Biophilic Design Analysis**, **Acoustic Comfort**, **Visual Comfort**, and **Ergonomic Mapping** revealed that access to natural light, views of green spaces, and a quiet environment improve patients' mental well-being and accelerate the healing process. Comparative benchmarking demonstrated that hospital designs in Germany, Japan, and Singapore achieve high performance in patient flow management, infection control, and energy efficiency through the integration of architectural layout and technological solutions. Based on these findings, the study recommends implementing functional modules, digital monitoring systems, and biophilic elements adapted to the Uzbek context.

Overall, the research confirms that integrating architectural and engineering approaches can enhance the functional efficiency of hospital buildings, improve patient safety and comfort, and ensure energy efficiency.

Conclusion

This study focused on examining and evaluating scientific and practical approaches for improving the architecture and functional planning of healthcare facilities. The results indicate that the effective operation of modern hospital buildings is directly linked to the proper organization of patient flows, clear separation of sterile and non-sterile zones, ensuring functional continuity between departments, and facilitating staff workflow. Findings from **BIM** and **CFD** modeling demonstrate that integrating architectural and engineering systems can significantly enhance infection control, improve energy efficiency, and reduce operational costs. Assessments of the psychological environment confirmed the direct impact of architectural elements on patients' mental state and stress levels. Implementation of **biophilic design**, strategic use of lighting and color, ergonomic layouts, and acoustic control were shown to create a comfortable psychological environment, thereby supporting faster recovery. Comparative benchmarking with international healthcare facilities revealed that hospitals in leading countries achieve high-performance in-patient safety, energy efficiency, and functional continuity, providing a solid reference framework for the adaptation of similar strategies in Uzbekistan.

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Overall, the study emphasizes three primary conclusions for the improvement of healthcare facility architecture: first, ensuring functional and technological continuity; second, enhancing infection control and patient comfort; and third, integrating energy efficiency and ecological sustainability. By adopting advanced technologies, digital modeling, and biophilic design elements, the quality and operational efficiency of the national healthcare system can be significantly improved. The findings of this research not only provide practical recommendations but also establish a robust scientific foundation for future studies in the field of healthcare architecture.

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