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DIGITALIZATION OF CONSTRUCTION: THE ROLE OF INFORMATION, ELECTRONIC, AND MECHATRONIC SYSTEMS IN ENSURING ENERGY EFFICIENCY

The modern construction industry is characterized by a transition to digital technologies aimed at improving the efficiency, reliability, and sustainability of buildings. One of the key challenges is reducing energy consumption while maintaining or improving indoor environmental quality. In this context, the integration of information, electronic, and mechatronic systems forms the technological basis for energy-efficient construction.

Information systems play a central role in the digitalization of construction processes. In particular, Building Information Modeling (BIM) technologies enable the creation of integrated digital models that include geometric, physical, and functional characteristics of buildings [1]. These models support energy analysis at the design stage, allowing engineers to evaluate different architectural and engineering solutions in terms of energy performance. Furthermore, BIM serves as a platform for data integration throughout the building lifecycle, from design to operation. An important extension of BIM technologies is the concept of the digital twin, which involves the synchronization of a digital model with real-time data from a physical object (Fig.1). This approach enables continuous monitoring of building performance and provides a basis for predictive analysis and optimization of energy consumption.

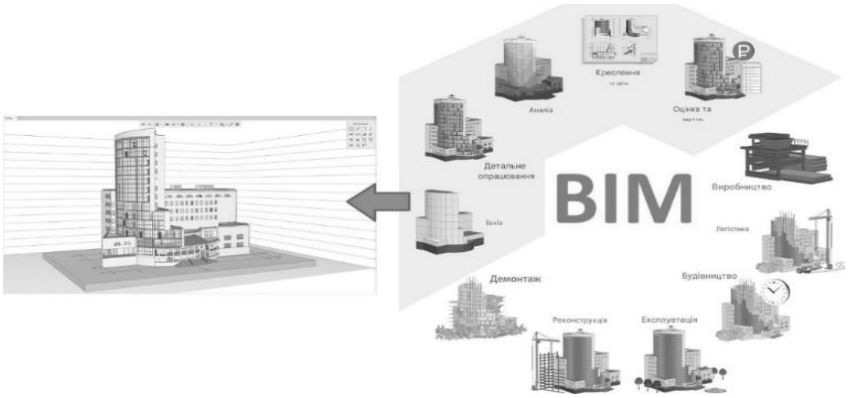

Fig. 1 – Life cycle of a construction object in a BIM environment

Electronic systems ensure the acquisition and transmission of data required for the functioning of digital models. These systems include various sensors and measurement devices that monitor environmental parameters such as temperature, humidity, CO_2 concentration, lighting levels, and occupancy. In

addition, smart metering systems allow for detailed tracking of energy consumption across different building subsystems. The collected data are transmitted to centralized platforms where they are processed and analyzed [2]. The role of mechatronic systems is to implement control actions based on processed information. These systems combine mechanical components, electronics, and control algorithms to regulate building engineering systems. Examples include automated HVAC systems, adaptive lighting systems, and dynamic shading devices. By adjusting system operation in real time, mechatronic systems can significantly reduce energy consumption while maintaining comfortable conditions for users. The integration of information, electronic, and mechatronic systems creates a unified intelligent environment for building management. In such systems, sensor data are continuously fed into a digital model, where they are analyzed to generate control commands. These commands are then executed by mechatronic systems, forming a closed-loop control system.

A practical example of this integration is the use of BIM-based energy management systems. At the design stage, a BIM model can be used to simulate energy consumption under various scenarios. During operation, real-time data from sensors are integrated into the model, enabling comparison between predicted and actual performance. Deviations can be identified and corrected through automated control systems. However, the adoption of such technologies also involves challenges, including high initial costs, the need for specialized expertise, and issues related to data interoperability and cybersecurity. Addressing these challenges requires the development of standards and the training of qualified professionals [3].

In the context of Ukraine's reconstruction and modernization, the application of digital technologies in construction is of particular importance. The integration of information, electronic, and mechatronic systems can significantly improve the energy efficiency of new and existing buildings, contributing to sustainable development and energy independence. Thus, the digitalization of construction based on the synergy of these systems represents a promising direction for the development of the industry. Further research should focus on improving integration methods, developing intelligent control algorithms, and expanding the use of digital twins in building management.

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