VISUALIZATION AND MODELING EFFICIENCY OF INTERIOR DESIGN PROJECTS IN BIM

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Abstract: *This study is devoted to the analysis of modern methods of visualization and presentation of interior design solutions within the BIM environment, as well as the optimization of processes for developing working documentation. In the context of increasingly complex architectural forms and higher requirements for engineering integration in interiors, traditional presentation methods are becoming insufficient for effective project coordination.*

The article examines methods for integrating BIM models with real-time rendering tools, virtual reality (VR), and algorithmic design approaches. The methodological framework of the study includes a comparative analysis of software systems (Autodesk Revit, Graphisoft ArchiCAD, Renga), a graph-analytical method for studying spatial relationships (Space Syntax), case studies of implemented high-tech projects, and design modeling based on the Diagrammatic BIM (D-BIM) framework.

The research results demonstrate that the application of BIM technologies can reduce design errors by up to 80%, decrease documentation processing time by 50%, and ensure high accuracy in cost estimation. The scientific novelty of the study lies in the systematization of automated annotation methods and in identifying the correlation between the Level of Development (LOD) and the effectiveness of interdisciplinary collaboration.

The practical significance of the research is confirmed by the developed recommendations aimed at improving the quality of presentation materials and reducing operational risks through the use of digital interior twins.

Keywords: *Building Information Modeling (BIM), interior visualization, working drawings, Level of Development (LOD), real-time rendering, digital modeling, interdisciplinary coordination, virtual reality.*

INTRODUCTION

The relevance of this study is driven by the rapid transformation of the architecture and construction industry toward full digitalization of the building lifecycle. In interior design—traditionally considered a field of "high art" and manual graphic expression—the adoption of BIM technologies has emerged as a response to the need for strict control over budgets, timelines, and the technical feasibility of complex design solutions.

A modern interior is no longer merely decorative; it has evolved into a complex ecosystem that includes automation systems ("smart home"), precision climate control, multi-scenario lighting, and custom furniture structures. Coordinating these elements within a unified space requires a fundamentally new level of visualization and documentation.

The evolution of presentation methods has progressed from watercolor renderings and hand drafting to photorealistic static images, and ultimately to dynamic information models. Today, “visualization” in BIM is not just a final image, but a design tool. The ability to instantly observe changes in lighting, materials, and spatial relationships (in Live Sync mode) transforms the very psychology of the creative process, allowing architects to operate not with lines, but with the physical properties of objects.

At the same time, working drawings generated from BIM models become dynamic specifications, where each element contains embedded information about its manufacturer, cost, and installation method.

The aim of this study is to systematize modern methods of visualizing interior design projects within the BIM environment and to develop optimal algorithms for presenting working drawings that ensure seamless information transfer from the designer to the contractor. To achieve this goal, the following tasks are addressed: examining the technological relationship between parametric modeling and the aesthetic presentation of a project; analyzing the effectiveness of different Levels of Development (LOD 100–500) in the preparation of working documentation sets; and evaluating the impact of real-time rendering tools and virtual reality (VR) technologies on the decision-making process and on minimizing cognitive biases among clients.

The object of the research is the process of designing and presenting interior solutions in a digital environment. The subject of the research is the methods of graphical and informational data representation in BIM systems. The scientific novelty of the work lies in substantiating the effectiveness of the diagrammatic approach (D-BIM) in interior design, which enables the integration of abstract compositional thinking with the logic of object-oriented modeling.

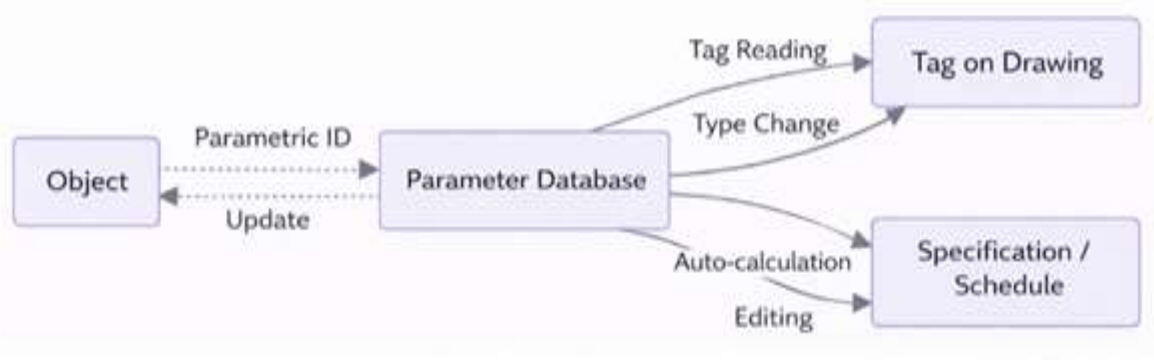

Figure 1.BIM Workflow and Visualization Pipeline

The practical significance of the study lies in the possibility of applying the identified patterns to optimize business processes in architectural firms, reduce the number of Requests for Information (RFI), and prevent costly revisions during the construction phase.

METHODS

The methodological framework of this study is based on a combination of theoretical research and empirical validation of hypotheses within a real design process. The first key method is a comparative analysis of leading BIM platforms and visualization tools. The study compares the functional capabilities of software products such as Autodesk Revit, Graphisoft ArchiCAD, and the domestic system Renga in terms of their applicability to detailed interior design. Particular attention is paid to the analysis of next-generation rendering engines, such as Enscape, Twinmotion, and D5 Render, which operate on real-time ray tracing technologies. The comparison is carried out according to criteria such as frame update speed, accuracy of PBR (Physically Based Rendering) material representation, and the depth of integration with project databases.

The second method is the graph-analytical approach to studying spatial configurations, known in international practice as Space Syntax. Within this framework, the interior is considered as a topological graph, where nodes represent functional zones or rooms, and edges represent physical or visual connections between them. The application of graph theory makes it possible to mathematically evaluate the efficiency of spatial planning solutions and to calculate indices of connectivity and accessibility.

The mathematical assessment of connectivity in this method is based on the integration formula:

$$\text{Integration} = \frac{\text{TotalDepth}}{\text{MeanDepth}}$$

where Total Depth is the sum of the shortest paths from a given space to all other spaces within the system. The application of this method within the BIM environment (through AVA plugins or Dynamo scripts) allows for an objective evaluation of spatial efficiency and human movement paths prior to the construction phase.

The third method is a case study approach (analysis of specific examples). The article examines the effectiveness of BIM implementation using high-tech projects such as Haeundae L and the Connecticut Proton Therapy Center as examples. These cases provide quantitative data on return on investment (ROI), reduction in clashes between interior solutions and engineering systems, and material savings achieved through accurate automated specifications.

The analysis includes a comparison of project indicators before and after the implementation of BIM processes, making it possible to verify hypotheses regarding a 20–50% increase in team productivity.

The fourth method is design modeling using the Diagrammatic BIM (D-BIM) framework. This method involves dividing the model creation process into three hierarchical stages: dissection (analytical decomposition of form into elementary components), articulation (definition of logical and parametric relationships between them), and actualization (enriching the model with structural and material information).

This approach makes it possible to maintain conceptual flexibility at early stages (LOD 200), while simultaneously preparing the data structure for the automatic generation of working drawings and specifications at the construction documentation stage (LOD 400).

RESULTS

The research results confirm the hypothesis that the effectiveness of presentation and the quality of interior project documentation directly depend on the depth of integration between graphical and informational layers of the model. It was found that the use of real-time rendering systems reduces the time required for client approval of design decisions by an average of 30–40%, as it enables virtual walkthroughs of the project without the long waiting times associated with static image production.

At the same time, the accuracy of lighting representation in systems such as Enscape and D5 Render has reached a level sufficient for making final decisions regarding the selection of finishing materials.

In the area of working drawing preparation, clear patterns have been identified regarding the influence of Level of Development (LOD) on the number of design errors. According to the analytical data, the transition from LOD 300 to LOD 350–400 in interior projects represents a critical threshold. At the LOD 350–400 level, connection and fastening elements (brackets, embedded parts, and junction nodes) are introduced into the model, which makes it possible to detect up to 90% of spatial clashes with engineering systems already at the design stage.

Table 1.Comparative Analysis of BIM Tools for Interior Design (2024–2025)

Comparison Criterion	Autodesk Revit	Graphisoft ArchiCAD	Renga (Russia)
Modeling logic	Parametric families	“Virtual building” approach	Object-based (minimalist)
Furniture libraries	Extensive (vendor-based)	Built-in (GDL objects)	Developing (style-based)
Drawing generation (elevations/sections)	Automatic (view-based)	Tool-based (view-driven)	Semi-automatic
Tag automation	High (Dynamo)	Property-based markers	Type-based tagging
Photorealism (internal engine)	Basic	High (CineRender)	Moderate
Learning curve	High	Medium	Low
Cloud collaboration	BIM 360 / Autodesk Construction Cloud	BIMcloud	Pilot-BIM
Morphological flexibility	Contextual masses	“Morph” tool	Direct editing
Compliance with standards (GOST/SP)	Requires templates	Requires templates	Built-in by default
IFC integration	Full (IFC 4.x)	High (OpenBIM)	Full (IFC4)

A particular focus should be given to the LOD 200 stage (Figure 2). At this stage, the interior is represented through approximated geometry, where the main elements have correct dimensions but simplified detailing. The results showed that the integration of AI tools (such as Veras) at this stage enables the designer to generate up to 10 variations of a room's atmosphere within 15 minutes, based solely on the basic massing of the model, significantly accelerating the conceptual design process.

Diagram Example (Mermaid):

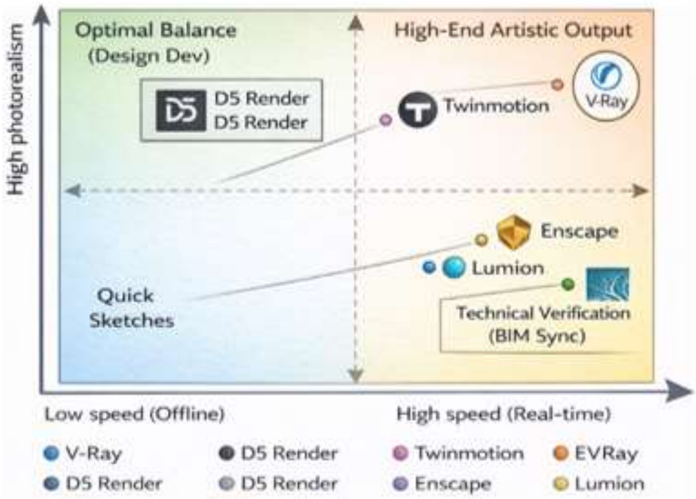

Diagram 1.Rendering speed vs. quality (2025)

A significant outcome was the implementation of annotation automation algorithms using Dynamo scripts. The use of intelligent tags that read material parameters directly from the project database eliminates discrepancies between the graphical documentation (plans) and specifications.

The time required to prepare a full documentation set using automation is reduced by 70%, while the accuracy of material quantity takeoffs reaches 99%, eliminating the need for "buffer" or excess procurement.

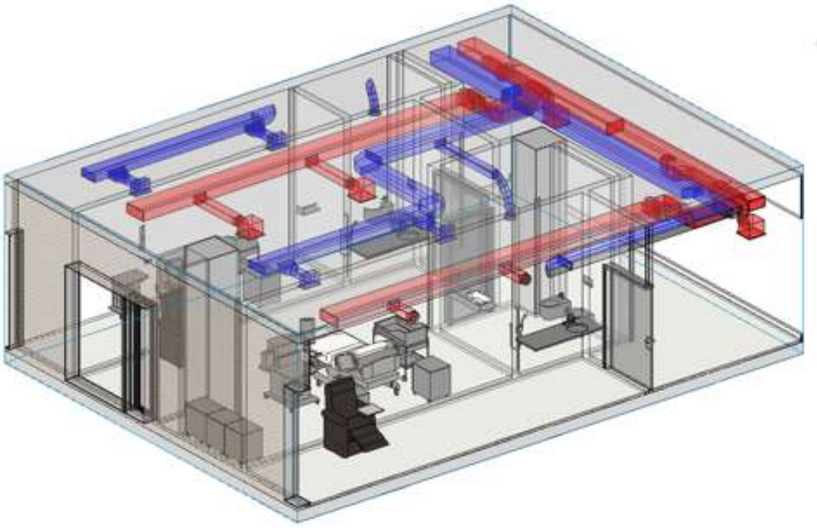

Figure 3.Technical Complexity Visualization (LOD400)

The case study of the Haeundae L project confirmed that the ROI from BIM implementation in complex interior projects is no less than 194.41%. This is achieved through the prevention of errors associated with schedule delays and the demolition of incorrectly constructed elements.

The study showed that indirect losses caused by construction delays due to design errors exceed the cost of corrective works by 194.69%. Thus, high-precision visualization of joints and connections in BIM becomes a tool for financial risk hedging.

DISCUSSION

The interpretation of the obtained results indicates a fundamental shift in the understanding of the role of “visualization” in the architectural process. Whereas visualization was previously considered merely a representational layer of a project, within the BIM environment it becomes a form of data control. The ability to instantly switch between photorealistic views and analytical modes (such as clash detection and lighting analysis) transforms the model into a living system.

Comparison with international studies confirms a global trend: BIM technologies enable the reduction of up to 40% of unplanned budget changes.

However, the implementation of BIM in interior design practice faces several limitations. The primary barrier is the “entry threshold,” which involves significant investments in staff training and hardware infrastructure (such as RTX-level graphics cards), thereby increasing the cost of an architect’s workstation.

In addition, there is a risk of “information noise”: excessive detailing at early stages may slow down the creative decision-making process. In this regard, the Diagrammatic BIM (D-BIM) concept provides a solution, allowing designers to work with abstract masses and relationships without overloading the system with construction details until the conceptual phase is finalized.

The role of artificial intelligence (AI) in combination with BIM opens new horizons for design optioneering. The use of tools such as Veras or ChatGPT integrations within

Grasshopper enables the generation of design alternatives based on text prompts, using the geometry of the BIM model as a structural framework.

This significantly accelerates communication with clients; however, it also raises new questions regarding copyright and the professional responsibility of designers. In the future, autonomous systems for drawing validation are expected to emerge, capable of scanning models in real time for compliance with building codes and standards (SNiP and GOST), thereby minimizing the influence of the human factor.

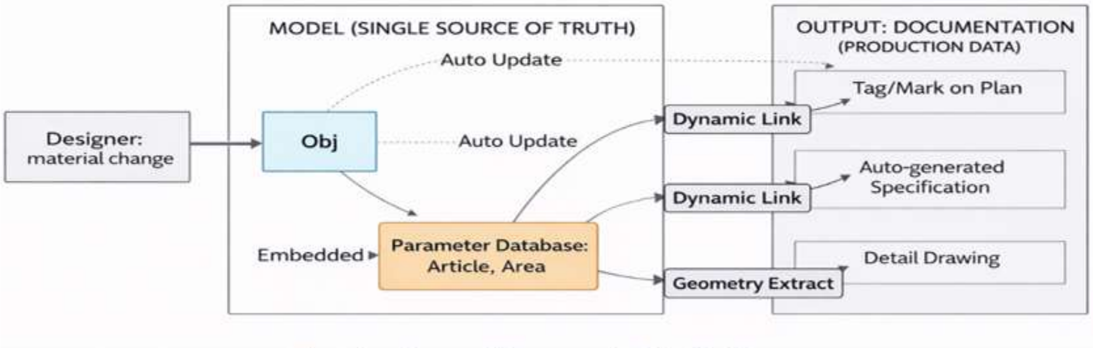

Figure 4. — Integrated Documentation Principle Scheme

Fragment of Code

The prospects for further research lie in the integration of BIM with augmented reality (AR) technologies for author supervision. The ability to overlay a project model onto the real-world environment during construction will allow designers to instantly identify deviations from the design.

Another relevant issue is the development of unified material libraries with digital passports, which would ensure the environmental sustainability of projects in accordance with the principles of a circular economy.

CONCLUSION

This study analyzed visualization and presentation methods for interior design projects within the BIM environment, as well as approaches to representing working drawings. The transition to BIM technologies represents a shift toward a new culture of information management. The main findings of the study are as follows:

1. Visualization in BIM has evolved from a presentation tool into an analytical one. Integration with real-time rendering engines (Enscape, D5 Render) provides continuous feedback, reducing approval timelines by 30–40%.

2. The quality of documentation is directly correlated with the Level of Development (LOD) of the model. Achieving LOD 350–400 is a necessary condition for effective coordination and for eliminating 80–90% of clashes at the design stage.

3. Automation of drawing production through intelligent tagging and parametric relationships ensures the “single source of truth” principle, eliminating errors in manual quantity takeoffs.

4. The application of graph-analytical methods and the D-BIM methodology enables effective management of project complexity, ensuring a transition from abstract concepts to detailed engineering solutions without losing creative intent.

Practical recommendations include the mandatory implementation of BIM Execution Plans (BEP), the use of real-time rendering systems for daily decision monitoring, and regular automated clash detection throughout the design process.

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