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Epistemological Ambiguity of Graphic Information in Construction and Drawing and its Impact on the Process of Designing and Implementing Construction Projects

Purpose. The purpose of this study is a systematic analysis of the nature of graphical ambiguity, the identification of its sources and manifestations, and the outlining of possible ways to minimize it. **Methodology.** The research employs an interdisciplinary approach that combines methods of epistemological analysis, visual semiotics, architectural graphics, and engineering communication. Within the study, a number of applied graphical models were developed representing typical sources of ambiguity. The method of comparative interpretation of graphic scenarios was applied to demonstrate the impact of ambiguous reading of drawings on the process of designing and implementing construction objects and structures. **Findings.** It was established that the epistemological ambiguity of graphical information arises from the interaction of several factors: the conventional nature of graphic symbols, the abstract character of drawings as models, differences in the professional competence of interpreters, and incomplete standardization and updating of documentation. It was also found that the use of BIM models and multimodal means of representation (2D + 3D + text) significantly reduces risks, although it does not completely eliminate ambiguity. **Originality.** The novelty of the study lies in a comprehensive investigation of epistemological ambiguity in the field of construction drawings from the perspectives of cognitive semiotics and architectural epistemology. The limitations of traditional standardization are identified, and the need to expand approaches to graphical communication in the context of contemporary digital architecture is substantiated. **Practical value.** The results can be applied in the professional training of architects, design engineers, and construction practitioners. The proposed recommendations on the use of multimodal information presentation tools (including BIM) can be integrated into internal regulations of architectural and construction companies in order to reduce errors and improve the quality of project implementation.

Keywords: graphical information; construction drawing; architectural drawing; epistemology; ambiguity; visual communication; design of construction projects; standardization; design; BIM

Introduction

Graphic drawing is the primary means of knowledge communication in architectural and construction design. However, it is not a neutral or unambiguous carrier of information: due to conventional symbols, projections, standards, as well as cultural, cognitive, and contextual factors, epistemological ambiguity arises – namely, uncertainty in how graphical information is interpreted. This paper analyzes the nature of this ambiguity, its sources and manifestations, and its potential consequences for the design and realization of construction projects. Based on contemporary research (in particular in design theory and architectural epistemology), ways of minimizing the risks associated with ambiguous interpretation are discussed, including standardization, multimodal representations (text, specifications, 3D/BIM), and the development of professional competencies. The paper concludes with findings and proposals for further research.

Construction and architectural drawings are not merely technical tools but also a means of conveying knowledge about a future structure: its form, structural system, spatial relationships between elements, engineering joints, functional connections, materials, and technologies. At the same time, a drawing is a model – a projection, a conditional representation – that cannot fully convey the

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entire complexity of an object, including its behavior over time, material properties, installation nuances, workmanship quality, and operational context.

From the perspective of epistemology, a graphic solution functions as a sign system with its own syntax (lines, hatching, scale, symbols), semantics (what a given symbol denotes), and pragmatics (how it is interpreted by a person). However, this system does not guarantee unambiguous understanding. Interpretation may depend on experience, context, cultural or professional standards, and on the subject who reads the drawing.

Therefore, in the process of design and construction, a scientific and practical problem arises: the epistemological ambiguity of graphical information, which can lead to errors, inconsistencies, misunderstandings, and ultimately to technical, organizational, or even safety-related risks.

Purpose

The purpose of this study is to conduct a systematic analysis of the epistemological nature of graphical ambiguity in the field of construction drawing as a specific form of visual knowledge functioning within architectural and engineering design.

Methodology

The study employs an interdisciplinary approach combining methods of epistemological analysis, visual semiotics, architectural graphics, and engineering communication. A qualitative analysis of sources examining the role of drawings as a form of knowledge and a sign system was conducted. Within the framework of the research, a series of applied graphical models were developed (a connection joint, a duct system in BIM, and a pipeline–beam conflict) representing typical sources of ambiguity. A method of comparative interpretation of graphical scenarios was applied to demonstrate the impact of ambiguous reading of drawings on the design and implementation of construction projects.

Findings

A graphic drawing is not merely a technical document but a complex form of representing knowledge about a future object. As a conditional model, it is unable to fully encompass all properties of a structure, including material behavior, technological nuances, and interaction with the environment. This limitation and conventionality give rise to potential ambiguity in perception. Within the construction process, a drawing acts as a mediator between the idea and its realization, between the design concept and the objectified form that materializes in space.

According to study [8], a drawing is not only a representation but also a form of thinking – an instrument of intellectual activity that enables reflection, clarification, and conceptualization of a future building. Study [9] adds that graphical elements are polysemic in nature and therefore always carry the risk of ambiguous interpretation. The graphical information embedded in a drawing is subject to interpretation depending on professional experience, level of training, context, and even the language used by specialists.

Study [10] emphasizes a profound gap between the abstraction embodied in a drawing and its actual materialization in a building. This gap inevitably generates a zone of uncertainty in which information is transformed under the influence of numerous variables. A drawing does not fix the object but presents it as a conditional system of coordinates, signs, proportions, and symbols that require shared interpretation and understanding.

Among the sources of ambiguity in graphical information, several key categories can be distinguished. First, there is the polysemy of graphical elements, where the same line or symbol may have different meanings depending on context, drawing scale, standards, and traditions within a particular architectural environment. For example, (Fig. 1) illustrates a beam-to-column connection joint in which different types of hatching (according to various DBN or ISO standards) may denote timber or lightweight concrete, depending on the regional standard. Second, there are the limitations of conventional symbols – for instance, hatching or symbols do not always fully describe complex engineering joints or technological operations.

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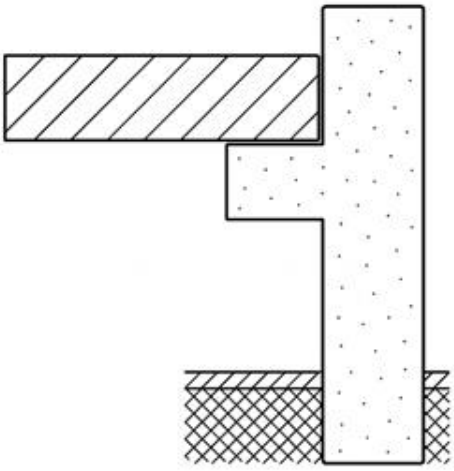

Fig. 1. Beam-column connection node

Fig. 2 presents different representations of the same ventilation duct: in a floor plan, in a section, and in a 3D BIM model, demonstrating how part of the information is lost when transitioning to 2D.

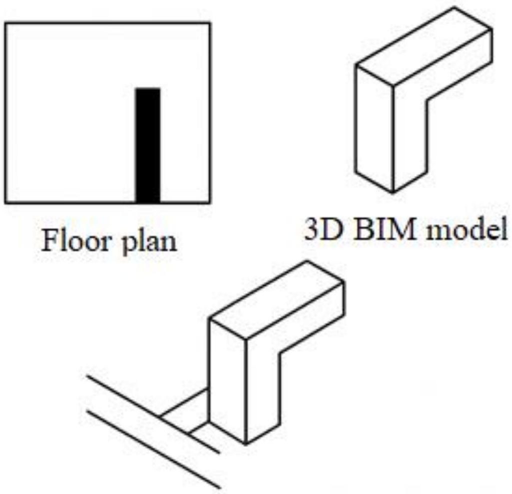

Fig. 2. Different methods of representing a ventilation duct: 2D plan, 3D BIM model

Third, there is a gap between the drawing and actual construction: the design is modified, supplemented, and refined, while the drawings sometimes do not reflect the latest updates. An example is a situation in which an installation crew routed a pipeline according to a previous version of the drawing, without considering clarifications introduced in the latest revision. This resulted in a conflict with a reinforced concrete beam that had not been accounted for in the earlier version (Fig. 3).

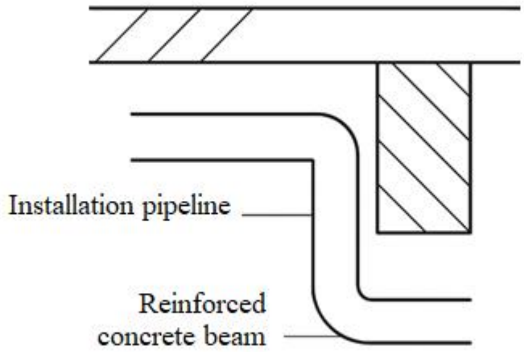

Fig. 3. Intersection of an installation pipeline with a reinforced concrete beam

In addition, the human factor cannot be ignored: differences in experience, knowledge, education, and even linguistic environment (for example, within international teams) lead to ambiguities in the perception of drawings. In some cases, elements of a drawing are interpreted differently by an engineer and a construction worker, creating risks of errors or incorrect execution. Technical changes or operational revisions are also not always immediately reflected in drawings, which contribute to the loss or distortion of information.

Such sources of ambiguity have serious consequences [3–7]. They may lead to technical errors – for example, the installation of structures in incorrect positions, improper use of materials, or noncompliance of the executed work with design requirements. At the organizational level, communication failures may arise between the client, the designer, and the contractor. This can result in additional costs, delays, and legal disputes regarding compliance of the facility with the documentation.

However, not all ambiguity is negative. In the design process, uncertainty can be productive, stimulating creative exploration, alternative solutions, and reflective engineering. The problem arises when such uncertainties are not regulated, controlled, or adequately explained in the final documentation.

The minimization of epistemological ambiguity is possible through several key approaches. First and foremost is standardization: the use of generally accepted drawing standards (DBN, ISO), unification of symbols, and common requirements for scales, projections, fonts, and related elements. Next are multimodal representation tools: textual

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explanations, tables, specifications, BIM models, and 3D visualizations. These helps compensate for the limitations of purely graphical representation by enhancing contextual understanding.

Equally important is the training of professionals: education, training programs, and continuing professional development focused on reading and interpreting drawings, familiarity with new standards, digital platforms, and modeling tools. Particularly relevant is the development of skills for critical reading of graphical information, the ability to identify potential zones of ambiguity, and the timely coordination of these issues with other participants in the process. As noted in [1], the importance of competent drafting and the ability to correctly interpret graphical data underscores the significance of "graphical literacy" which is directly related to the issue of ambiguity.

New technologies play a dual role: on the one hand, they reduce uncertainty (for example, through BIM, interactive models, and clash detection); on the other hand, they create new challenges (different software environments, file formats, incompatibilities, and the need for IT competencies). A systemic approach to their implementation is required, involving coordinated collaboration among all participants, a shared digital platform, and transparent procedures for project changes.

Despite the outlined strategies [2], the complete elimination of epistemological ambiguity is hardly possible. It is part of a deeper cognitive process related to how we think, imagine, represent, and construct space. Therefore, the goal is not to eliminate ambiguity, but to critically reflect on it, manage it, and integrate it into engineering culture.

Graphic drawing is a complex sign system whose interpretation depends on many variables. Epistemological ambiguity is an inherent feature of drawings that requires not elimination, but understanding and management. Raising standards, developing graphical literacy, and integrating digital tools are the main strategies for minimizing risks. Further research should focus on empirical case studies and regulatory frameworks. Equally important is the study of the role of ambiguity as a resource for innovation in design and its impact on the quality of the architectural environment.

Originality and practical value

The scientific novelty of the study lies in a comprehensive interdisciplinary approach to examining the phenomenon of epistemological ambiguity in construction drawing, integrating the theoretical foundations of cognitive semiotics, architectural epistemology, and visual communication.

A systematic investigation of the factors that give rise to ambiguity in the interpretation of graphical information during the design and realization of construction projects has been carried out. A typological classification of sources of graphical ambiguity is proposed, including lexical (polysemy of signs), syntactic (differences in standards, scales, and projection systems), pragmatic (the human factor), and procedural (the gap between drawing versions and actual project changes).

An innovative aspect of the research is the development and implementation of graphical illustrations that visually represent the most common scenarios of ambiguity at the stages of reading, transmitting, and executing drawings. These illustrations not only strengthen the theoretical framework of the study but also have applied value in education and architectural modeling practice.

In addition, the paper substantiates the limitations of traditional approaches to drawing standardization (DBN, ISO) in the context of the increasing complexity of digital projects. The necessity of transforming the concept of graphical communication – from linear data transmission to multimodal interaction incorporating 3D, BIM, textual, and analytical components – is argued. This approach opens prospects for rethinking the role of drawing within the system of architectural knowledge as a flexible yet critically controlled instrument of design thinking.

Conclusions

Graphic drawing in the fields of architecture and construction functions not only as a technical tool for recording design decisions, but also as a sign system operating within a complex process of communication and knowledge transfer. Its interpretation depends on numerous variables, including the level of professional training of project participants, compliance with standards, the con-

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text of use, and the technological environment in which it is created and applied.

The conducted analysis demonstrates that epistemological ambiguity is not an accidental malfunction of the system of graphical communication, but an inherent characteristic of it. This ambiguity cannot be completely eliminated due to the abstract nature of drawings, their limitations as models of reality, and their dependence on subjective interpretation. At the same time, it can be systematically managed through institutional, educational, and technological mechanisms.

Key strategies for minimizing risks caused by ambiguity in graphical information include:

– increasing the level of standardization of graphical representation based on international and national norms (DBN, ISO, BIM protocols);

– developing graphical literacy among professionals, particularly the formation of critical thinking when reading drawings and the ability to identify and reconcile interpretative discrepancies;

– integrating digital tools – such as Building Information Modeling (BIM), 3D visualization, and interactive drawings – as means of reducing abstraction and enhancing the contextual richness of graphical information.

Particular attention should be paid to the study of empirical cases – real examples of technical errors, design conflicts, or legal disputes caused by ambiguity in graphical documentation. Such empirical material should form the basis for the further development of methodological recommendations, educational standards, and, where necessary, changes in the regulatory framework.

Overall, the proposed approach is aimed at rethinking architectural drawing as a living, dynamic, and context-dependent form of knowledge that requires not only precision in execution but also a deep understanding of its epistemological nature by all participants in the construction process.

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Епістемологічна неоднозначність графічної інформації в будівництві й кресленні та її вплив на процес проєктування й реалізації будівельних проектів

Мета. Метою цього дослідження є системний аналіз природи графічної неоднозначності, виявлення її джерел та проявів, а також окреслення можливих шляхів її мінімізації. **Методика.** У дослідженні застосовано міждисциплінарний підхід, що поєднує методи пістемологічного аналізу, візуальної семіотики, архітектурної графіки та інженерної комунікації. В рамках дослідження розроблено низку прикладних графічних моделей, що репрезентують типові джерела неоднозначності. Метод порівняльної інтерпретації графічних сценаріїв застосовано для демонстрації впливу неоднозначного прочитання креслень на процес проектування та реалізації будівельних об'єктів і споруд. **Результати.** Встановлено, що епістемологічна неоднозначність графічної інформації виникає внаслідок взаємодії декількох факторів: умовної природи графічних символів, абстрактного характеру креслень як моделей, відмінностей у професійній компетентності інтерпретаторів, неповної стандартизації та актуалізації документації. Також було виявлено, що використання BIM-моделей та мультимодальних засобів представлення (2D+3D+текст) суттєво знижує ризики, хоча й не усуває повністю неоднозначності. **Наукова новизна.** Новизна дослідження полягає у комплексному дослідженні епістемологічної невизначеності у сфері будівельних креслень з позицій когнітивної семіотики та архітектурної епістемології. Виявлено обмеження традиційної стандартизації та обгрунтовано необхідність розширення підходів до графічної комунікації в контексті сучасної цифрової архітектури. **Практична значимість.** Результати дослідження можуть бути застосовані у професійній підготовці архітекторів, інженерів-проектувальників та будівельників-практиків. Запропоновані рекомендації щодо використання мультимодальних засобів представлення інформації (зокрема BIM) можуть бути інтегровані у внутрішні регламенти архітектурно-будівельних компаній з метою зменшення кількості помилок та підвищення якості реалізації проектів.

Ключові слова: графічна інформація; будівельне креслення; архітектурне креслення; епістемологія; неоднозначність; візуальна комунікація; проектування будівельних об'єктів; стандартизація; дизайн; BIM

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