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Digitization of AEC Industries Based on BIM and 4.0 Technologies

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Abstract: BIM and 4.0 technologies are currently the leading branches of digitization in construction. The aim of this article is to confront theses on building information modeling (BIM) and coexisting technologies, and to present an analysis along with conclusions regarding the digitization process of AEC industries using BIM methodology and advanced digital technologies within the scope of 4.0 technologies. Key aspects of BIM and 4.0 technology integration were discussed, including artificial intelligence (AI) or big data and data science analytics. The impact of these fields on design processes, as well as on data management, monitoring of design and construction progress, and overall efficiency of AEC industries, was analyzed. The article pays particular attention to the synergy between BIM and 4.0 technology, identifying benefits, challenges, and development perspectives. Conclusions indicate the growing importance of interdisciplinarity for improving AEC industry processes and the need to adapt to the changing digital landscape in the field of design and construction. A survey was conducted, where respondents' answers were presented in the form of charts. Questions focused on the issue of the use of BIM methodology along with coexisting technologies in the design process by the Polish engineering staff. The research results indicate that the use of the latest technological solutions in Poland is still rare, and the digital potential of these solutions is not fully utilized. The article can make a significant contribution to the discussion on technological evolution in AEC industries, identifying development directions in the context of digitization and the use of the latest achievements of 4.0 technology. Previous research has not included such a wide spectrum of BIM use in Poland. An analysis was conducted comparing Poland in a global context with other countries in BIM adoption.

Keywords: BIM; ISO 19650; AEC; metadata; CDE; 4.0 technologies

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1. Introduction

A common phenomenon in the collective consciousness regarding BIM is identifying it with a 3D model of a given building object. BIM is primarily metadata contained in the 2D, 3D, or even 4D to 7D model [1]. The quality and completeness of this metadata are crucial for the implementation of the project in this methodology [2]. In today's times, in the era of dynamic technological development, digitization is one of the key factors influencing the development of the construction industry [3]. The application of BIM (building information modeling) methodology and the ISO 19650 standard [4–8], along with VR (virtual reality), AR (augmented reality), VDC (virtual design and construction) technologies, and the CDE (common data environment), allows for increased work efficiency, improved design quality, and a reduction in costs and project implementation time [9–11].

Artificial intelligence (AI) is a relatively new phenomenon that can be successfully implemented for designing and managing the entire life cycle of an object [12]. This combination has enormous potential to change the way construction schedules, costs, quality, and cybersecurity are managed, which contributes to increasing the overall efficiency and effectiveness of the projects being implemented. However, the integration of BIM and AI generates its own challenges, and understanding these difficulties is key to the effective implementation and development of this cooperation [13,14]. It should also be noted that the combination of BIM with ESG (environmental, social, governance) brings a number of benefits such as increased energy efficiency, improved quality of life, transparency, and responsibility [15]. It is worth noting that many significant academic universities in Poland conduct research and postgraduate studies in BIM, which reflects market demands and trends that are currently in the AEC industry [16]. The authors look at the above-mentioned aspects as providing opportunities and broad research horizons, and the issues of their implementation may constitute an interesting research gap. The least explored and described is the integration of BIM with AI, which the authors want to dedicate future research to.

Currently in Poland, there is no requirement to use BIM in public procurement, unlike in some countries, such as Norway or the United Kingdom [17,18]. Nevertheless, in our country, there is an ongoing debate in the industry environment about the appropriateness of introducing such regulations [19]. In March 2022, a working group for BIM was established in the Ministry of Development and Technology, which is responsible for developing a strategy for implementing BIM in Poland and supporting the Minister in related activities [20]. It is worth mentioning that in the previously mentioned countries, there are strictly defined requirements regarding BIM, such as the level of representation of design models (LOD), model size, native and non-native formats, and much more [21,22].

2. Materials and Methods

For the purposes of this study, a survey was conducted to examine the degree of BIM usage among the Polish engineering staff. The survey consisted of 22 questions, which were carefully designed to obtain the broadest possible picture of the current state of BIM methodology usage in AEC industries. The survey questions covered various aspects related to BIM, such as the level of awareness about BIM, experience in its use, obstacles encountered during BIM implementation, and potential benefits resulting from its use. This study is part of a broader project aimed at understanding how digitization and 4.0 technologies influence AEC industries, and in particular how they are used to improve efficiency, quality, and sustainable development in these sectors [23]. The results of this survey will be analyzed and discussed in the further part of this article, and the conclusions drawn from them will help in understanding the current state of BIM usage in Poland and in indicating possible directions for its further development. The presented analysis used three research methods: Survey research, literature review, and the professional experience of the authors from design and implementation work, where the BIM methodology was used from level 0 to level 3 (Figure 1). The survey was attended by research workers from the Warsaw University of Life Sciences and employees of the largest construction companies in Central Europe, as well as representatives of small and medium-sized companies. Additionally, in order to eliminate statistical error, the questions were constructed in such a way as to check the reliability of the results. This resulted in the removal of 13 respondents from the study. The article uses the latest scientific literature on BIM and related technologies and is based on professional experience gained on contracts such as the Hinkley Point C Nuclear Power Plant in the UK, the expansion of the Kennedy Airport terminal in NY, USA, or the Central Communication Port (airport and railway network) in Poland and many more.

2.1. What is BIM

BIM is the process of generating and managing data about a building object throughout its entire life cycle—from the design phase to demolition [24] (Figure 2). It uses multidimensional, spatiotemporal, dynamic models of the aforementioned building objects, which are data-rich and are updated in real time. These models are created using specialized BIM software available on the market (among others: Autodesk Revit, Tekla Structures, Archicad, Nemetschek Allplan) and can be used by all project participants, from architects and engineers, to contractors and property managers [25].

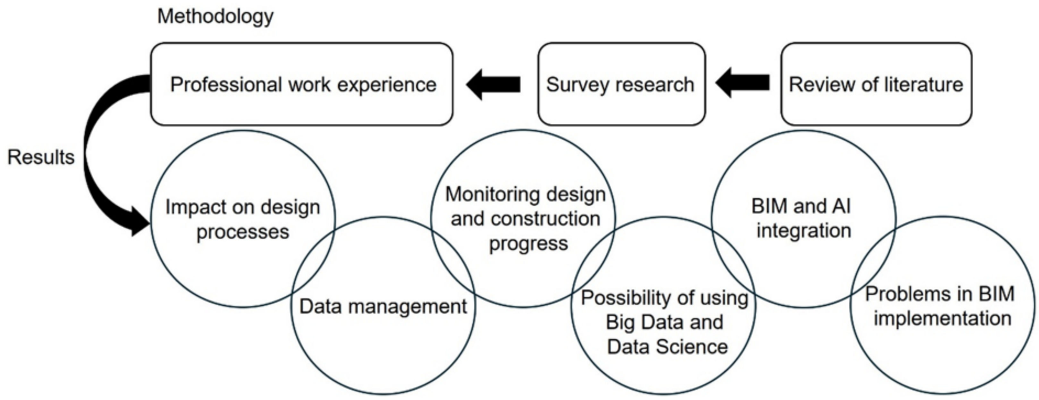

Figure 1. Research methodology diagram.

BIM methodology has many advantages that make it an extremely valuable tool in AEC industries. First, it allows for better communication and coordination between various teams working on the project. Second, it improves the accuracy and quality of the design, leading to fewer errors and delays. Third, it enables better resource and cost management, resulting in greater efficiency and savings [26].

In summary, BIM is a powerful resource of tools that revolutionize the way we manage information in construction. The ability to integrate large amounts of data into one easily accessible model makes it extremely valuable for all project participants. Therefore, understanding what BIM is and how to effectively use it is key to the future of the construction industry. At this point, it is worth noting that construction has constituted a significant percentage of Poland's GDP over the years [27]. As can be observed, this is a significant element of our economy, and its modernization will influence the number of new investments through financial optimization of projects, especially those infrastructural. Therefore, it is of great importance to introduce BIM in public procurement by law [28].

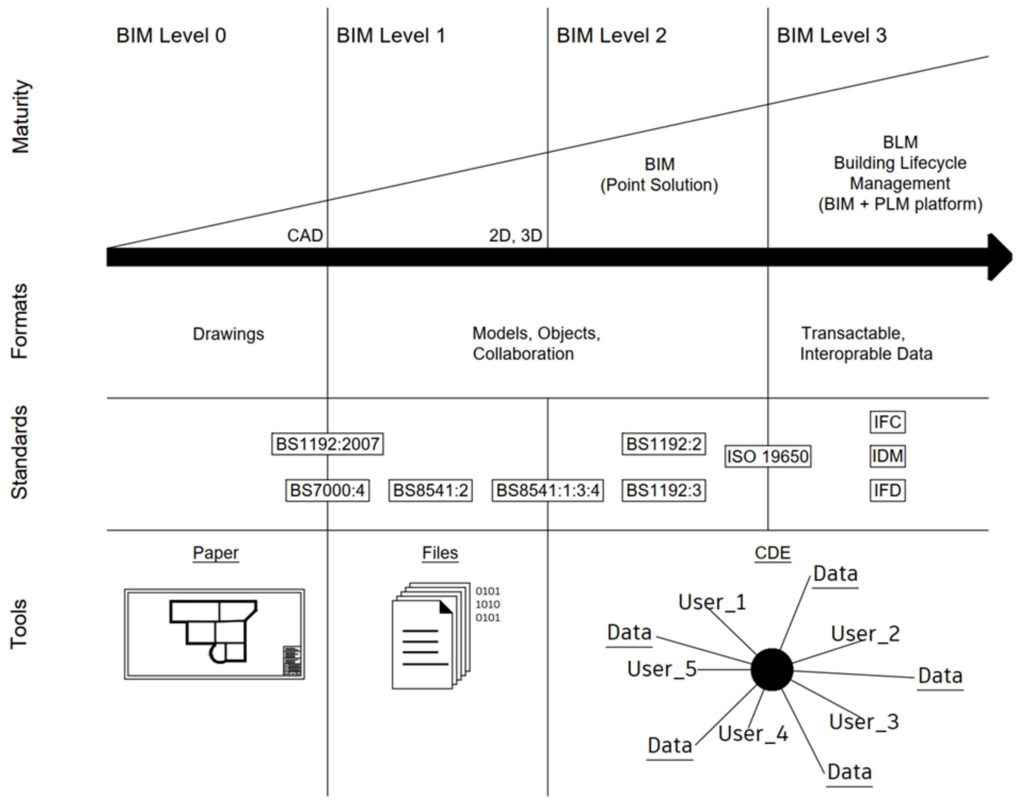

Figure 2. Levels of BIM development [4–8,29–36].

2.2. LOD Models Levels of Detail

Levels of Development (LOD) are a key aspect of building information modeling. They indicate the degree of accuracy and completeness with which building objects are represented in the BIM model. There are several standards and definitions regarding LOD, but the most popular and commonly used are the definitions developed by the American Institute of Architects (AIA) and BuildingSMART International [37]. The LOD level is shaped by different phases of the project and their specifics. The higher the degree of project advancement, the higher the LOD level (Figure 3). However, this is also influenced by the EIR (Exchange Information Requirements) document, which is increasingly attached to the tender documentation in Poland by the Ordering Party. In this document, we have detailed requirements for information exchange on the project, including LOD [38]. Based on this document, the contractor is obliged to create and present a BEP (BIM Execution Plan) document, in which he indicates how he intends to meet the investor's BIM requirements.

$$\text{LOD} = \text{LOG} + \text{LOI}$$

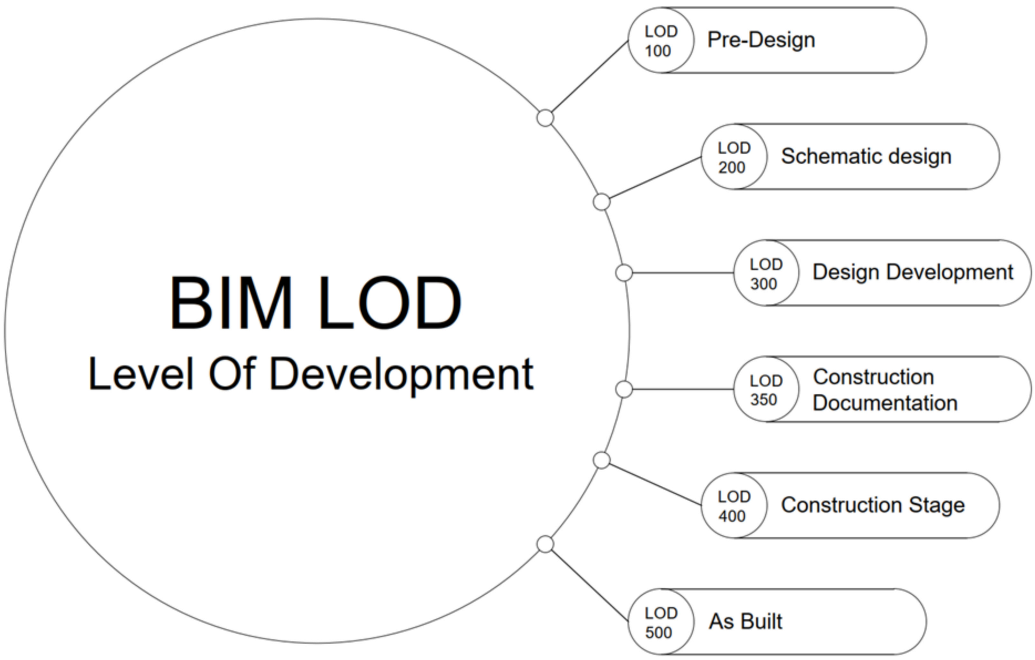

Figure 3. Level of detail—LOD models (LOI + LOG).

LOG (level of geometry) refers to the external, visible aspect of the model, which expresses the level of detail of its geometric configuration. For example, EMCS 4.0 distinguishes 5 different levels, where LOG 1 means a schematic or symbolic representation of the product, and LOG 5 means a detailed, manufacturer-specific representation. LOI (Level of Information) is the invisible, non-geometric part of the BIM model, which expresses the information and technical data of the model. High-level LOI content includes, for example, object-specific information such as dimensions, materials, technical cards, etc. As the project progresses, both the level of geometric detail and the level of information usually increase. However, there can be large differences between LOI and LOG. A component can have a symbolic representation, while the information is fully specified, including manufacturer-specific properties. In the AIA definition, LOD is divided into six levels, marked from 100 to 500 [39]. Here is a detailed explanation of each level:

- LOD 100: This level represents conceptual and sketch models of the building. Objects are represented as a simple shape or symbol, not containing detailed geometric information or properties. Examples are rectangles symbolizing walls or circles symbolizing columns.

- LOD 200: At this level, models contain more detailed geometry, as well as basic information about the object, such as dimensions, location, spatial relationships, etc. LOD 200 models are used for spatial analysis, e.g., for determining room areas.
- LOD 300: Models contain complete information about the geometry of objects, including shape, size, orientation, construction, and other details. LOD 300 models are used to develop detailed architectural designs, such as room layouts, elevations, sections, etc.
- LOD 350: This level is similar to LOD 300, but also includes information about specific components and systems, such as electrical, ventilation, hydraulic installations, etc. LOD 350 models are used for system integration and collision analysis.
- LOD 400: Models contain detailed information about specific components, such as 3D models, specifications, parameters, equipment, etc. LOD 400 models are used for precise planning and coordination of individual building elements.
- LOD 500: This level represents an as-built model, which contains actual information about the building, such as the condition of existing elements, maintenance information, maintenance recommendations, etc. LOD 500 models are used for managing and maintaining the building after it has been put into use.

The above levels are guidelines and may vary depending on the project and industry specifics. It is important to precisely define the LOD level that will be appropriate for a specific application of the BIM model, to enable accurate and effective use of building information [40].

2.3. Metadata and CDE, an Opportunity for Big Data and Data Science

Metadata is structured information that describes an information container, i.e., an information resource [41]. They can provide details about the content, context, structure, and other aspects of the resource, making it easier to search, manage, and use. In conjunction with the common data environment (CDE), they are key elements in the BIM methodology. In the context of BIM, metadata can include information about the author of the model, the date of creation, the software used, as well as details about individual elements of the model, such as materials, dimensions, location, and many others. Metadata is essential for effective management and use of the information contained in the BIM model [42].

The common data environment (CDE) is a central database that allows for transparent and secure management of project resources [43]. CDE promotes clear and understandable communication between project members, which in turn affects transparency in the construction schedule and eliminates misunderstandings. CDE is essential for the effective management of information and data used in the BIM process. Two key aspects of using CDE focus on project collaboration and management, including:

- Recording a full audit trail of the built resource through a highly secure, immutable, and neutral environment—all project information is stored on one platform, but project participants have access only to the information they are authorized to—this is very well described by the ISO 19650 standard [44].
- Finding efficiency in the production of coordinated and current information, reducing both time and cost [45].

Therefore, metadata and CDE are extremely important for the effective implementation of the BIM methodology. They help in managing information, improve communication and collaboration between project teams, and also enable better management of construction projects. It is worth noting that the CDE platform is required at the second level of BIM. Big data refers to large data sets that are too large or complex to be processed by traditional methods [46]. In the context of CDE, big data can include huge amounts of data generated by various aspects of a construction project, such as data from BIM models, project or building management systems, and many others. Data science is a discipline that uses scientific methods, processes, algorithms, and systems to extract knowledge and insights from data in various forms, both structured and unstructured [47]. Considering CDE, data science can be used to analyze and interpret large data sets to obtain valuable information that can help in decision making and improve project efficiency. For example, data science can be used to analyze data from BIM models to identify patterns that can help optimize the project, such as identifying frequently occurring problems that delay the project schedule, or identifying areas that can be optimized for cost. Therefore, big data and data science are not only possible but also crucial for the effective use of CDE in the BIM methodology on large contracts. In the future, with the increasing amount of data generated by construction projects and greater computing power available for analyzing this data, the possibilities of using big data and data science in CDE will likely increase [48].

2.4. The Future of BIM and Integration with AI

The integration of AI and BIM (as well as big data and data science, mentioned in Section 2.3) brings many opportunities for the AEC industry. This integration shapes a future where sustainable development, efficiency, cost, and time management are redefined. Artificial intelligence can analyze and learn from BIM data, providing valuable insights and solutions for architects, engineers, manufacturers, and other stakeholders [49]. AI can also support the generative design process, creating many alternative proposals based on specific parameters and constraints. For manufacturers, the AI-BIM integration means the possibility of digitizing their product catalogs, predicting market needs and trends, optimizing production processes, and delivering personalized solutions for customers. To achieve this, manufacturers need to develop a digital strategy that will define how to implement AI, manage data, upgrade employee skills, and measure success. AI and BIM are not only technology but also a change in culture and mentality. Companies that will proactively and creatively use these tools will be market leaders in the coming years. AI and BIM are an opportunity to create a new era for the AEC industry, where people and machines collaborate to create a better and more sustainable construction environment [50].

In 2023, we could talk about the dynamic development and popularization of the use of generative AI, and 2024 will probably bring an improvement in the quality of its work and its implementation in new areas. We already see the use of AI in practice. Research is underway on the design of structures with full integration of BIM and AI using data fusion between domains, i.e., image data and condition data, generating construction drawings [51]. Another study presents that project management, quality, construction schedule, or safety management, optimization, and integration are possible thanks to the symbiosis of BIM with AI, as proven by Nitin Liladhar Rane from the University of Mumbai [12]. We can draw conclusions about the advantage that new technologies give us in the entire design process over engineers who use traditional methods. The first software solutions, such as “Bimify” or “Propagate”, from the company Bricsys are already appearing on the market. Thanks to these tools, we can automatically assign BIM classification to geometry, analyze the source model, and then implement the same technical or architectural solutions on another model. Additionally, there is the possibility to increase the LOD of the model by analyzing and comparing all elements with each other and applying the same graphic and non-graphic data. The manufacturer’s team is currently working on a tool that allows for semi-automatic generation of 3D models from point clouds [52].

3. Results

Original research was conducted involving a survey among 124 people working in the AEC sector. A Google form was created and shared on social networks such as LinkedIn and Facebook. To achieve the research objective and verify the assumed working hypothesis, it was appropriately constructed. The survey consisted of 22 questions, many of them multiple choice, and was directed to people working in contracting companies, design offices, and design-build firms. The aim of the study was to check the knowledge and opinions of the respondents about the BIM methodology and the needs of digitization. The results are very disturbing, as they indicate large gaps in knowledge related to the need for digitization, the benefits associated with it, standardization, and a whole range of related things.

In design offices, 63 respondents (50.81%) work, 40 people (32.26%) in contracting companies, and 21 people (16.94%) in design-build firms (Figure 4).

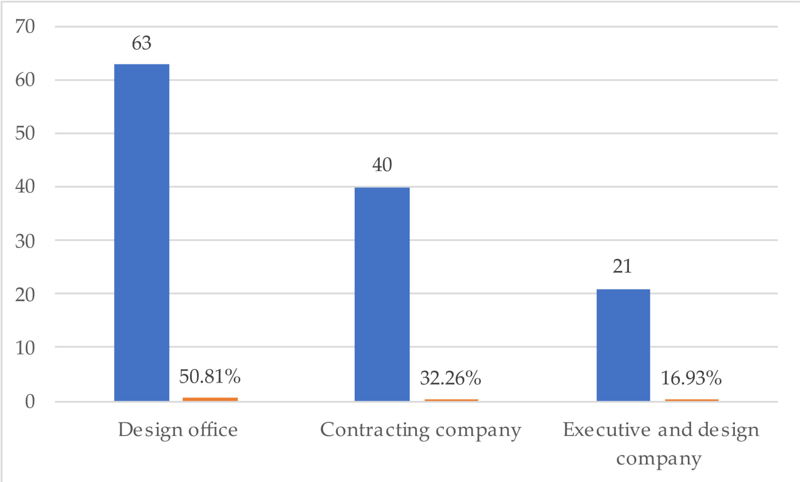

Figure 4. The respondents' place of employment.

The professions of the respondents are presented below. We can see that the vast majority of people are low- and mid-level employees. Therefore, the study results mainly focus on this group (Figure 5).

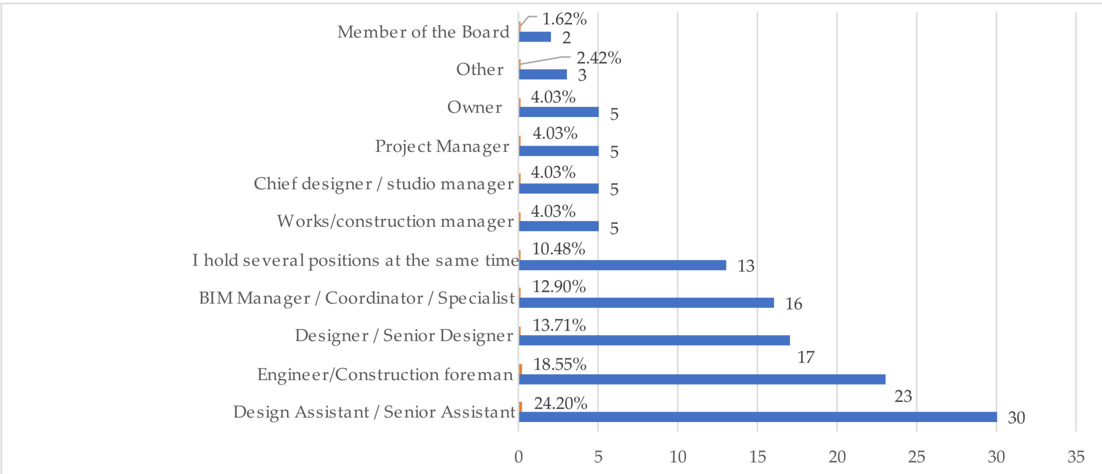

Figure 5. Respondents' position level.

Over 10% of respondents are research workers. This could have contributed to overestimating the survey results in the context of understanding what BIM is and what the benefits of its use are (Figure 6).

Education was also asked because it is very important information allowing for the interpretation of the study results. Over 95% of respondents have higher education, which translates into experience and level of knowledge in specific fields, including the AEC industry (Figure 7).

More than 70% of people do not have Polish construction licenses (Figure 8). This is the result of a declining trend over the years in Poland. Additionally, it is worth noting that some of the respondents work for foreign companies carrying out projects outside Poland, and in many countries, there are no construction licenses.

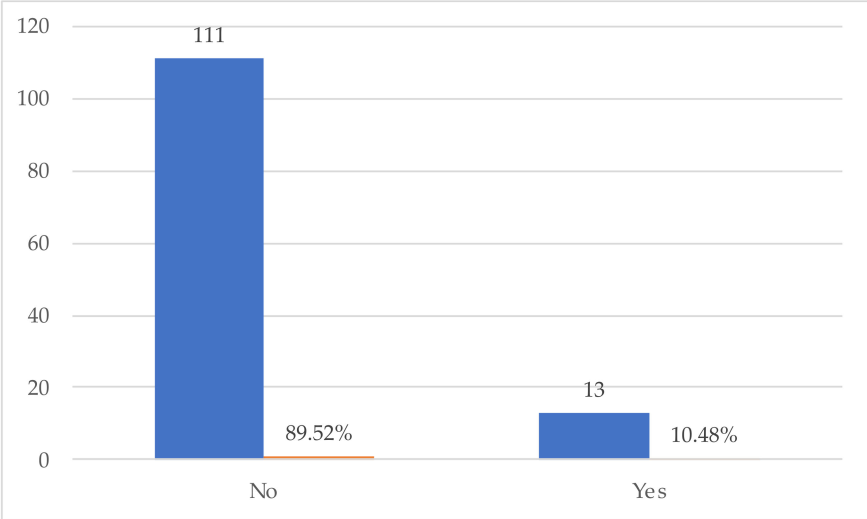

Figure 6. Number of scientific staff.

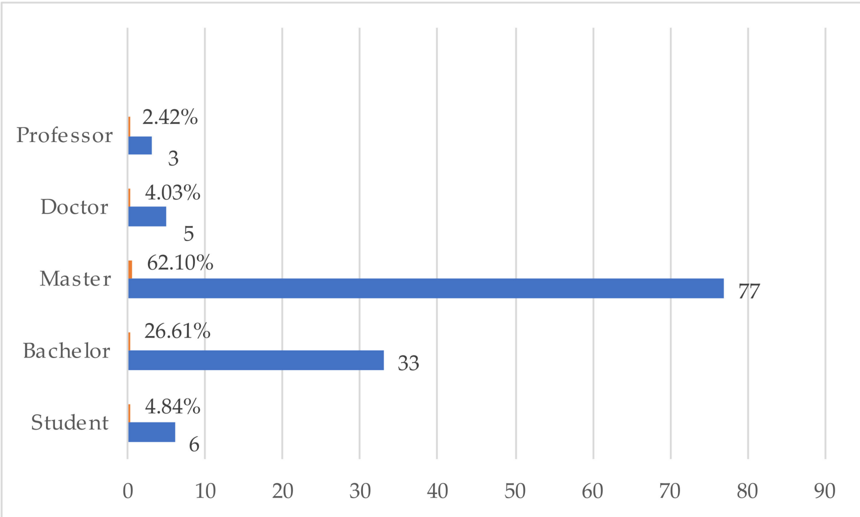

Figure 7. Level of education.

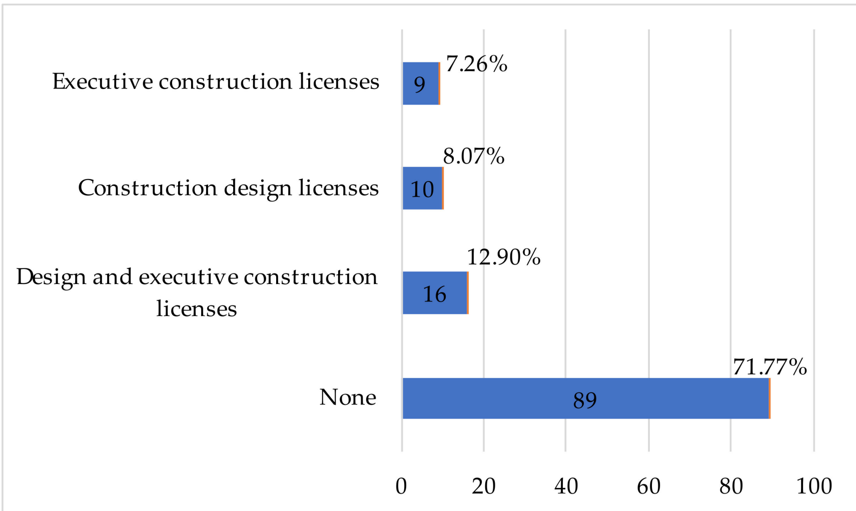

Figure 8. Possessed Polish construction licenses.

The specializations of the people participating in the study are as follows: We can see that the construction industry is the most popular, as much as over 48%. BIM is most often used in building construction, which is a global trend. Architectural and structural specializations are also the most popular in Poland (Figure 9).

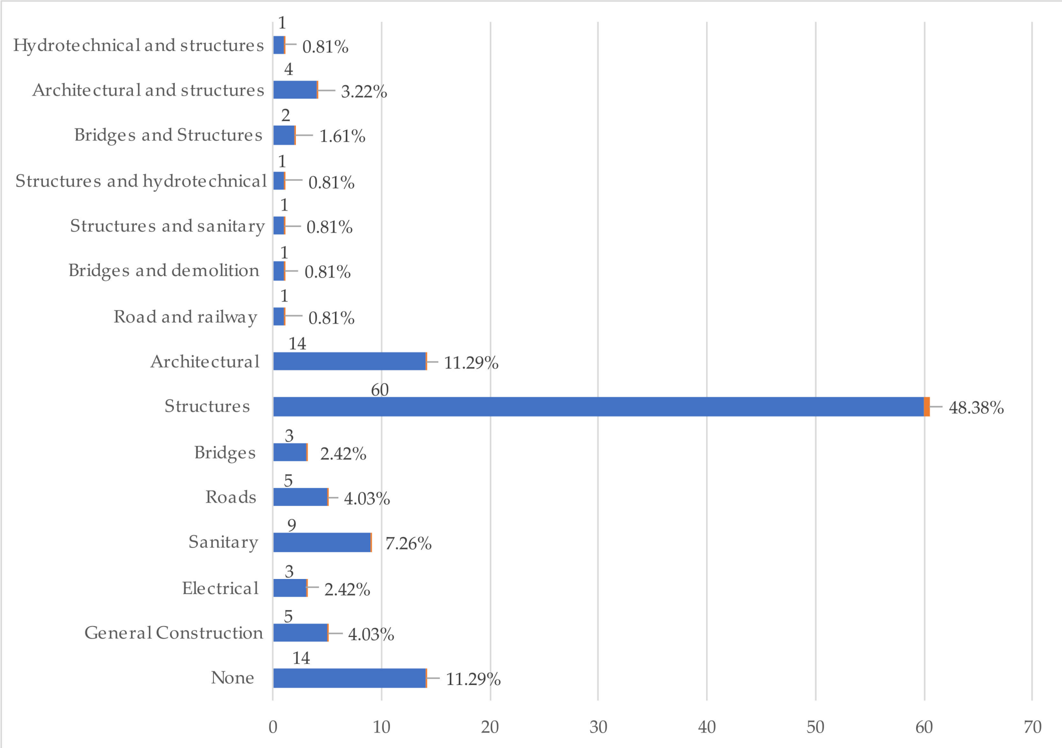

Figure 9. Specializations of respondents.

The survey is dominated by employees of large and medium-sized companies (Figure 10). We can expect the use of BIM in these companies due to the awareness of the management staff and the costs associated with the implementation of new technologies. To a large extent, small companies cannot afford this.

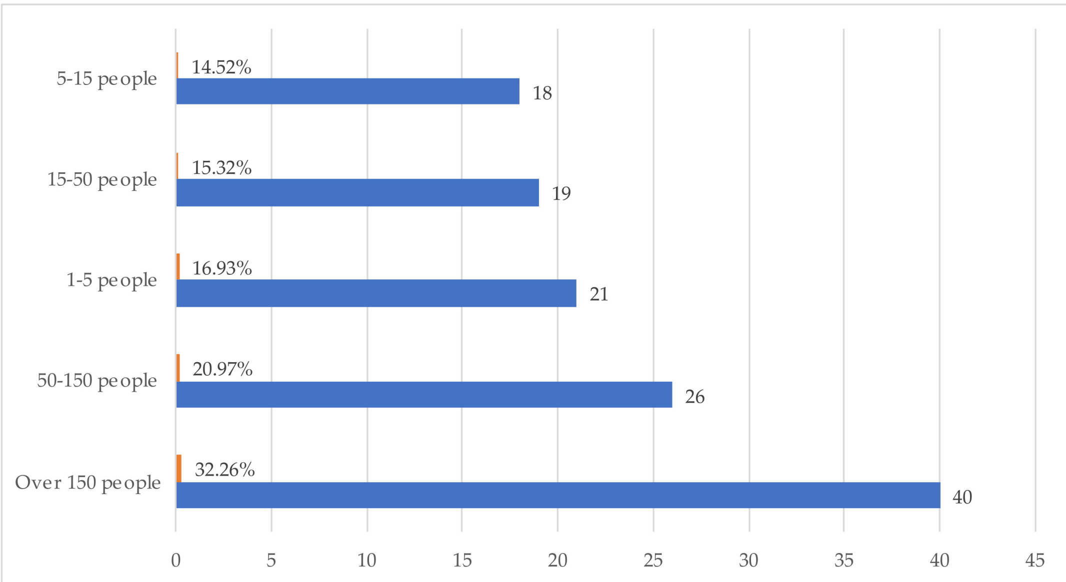

Figure 10. Size of companies.

The question was intended to illustrate the dispersion of Polish engineers among companies with different capital (Figure 11). This has a significant impact on the use of BIM on projects, due to the fact that conducting projects in this methodology is not required by Polish legal acts.

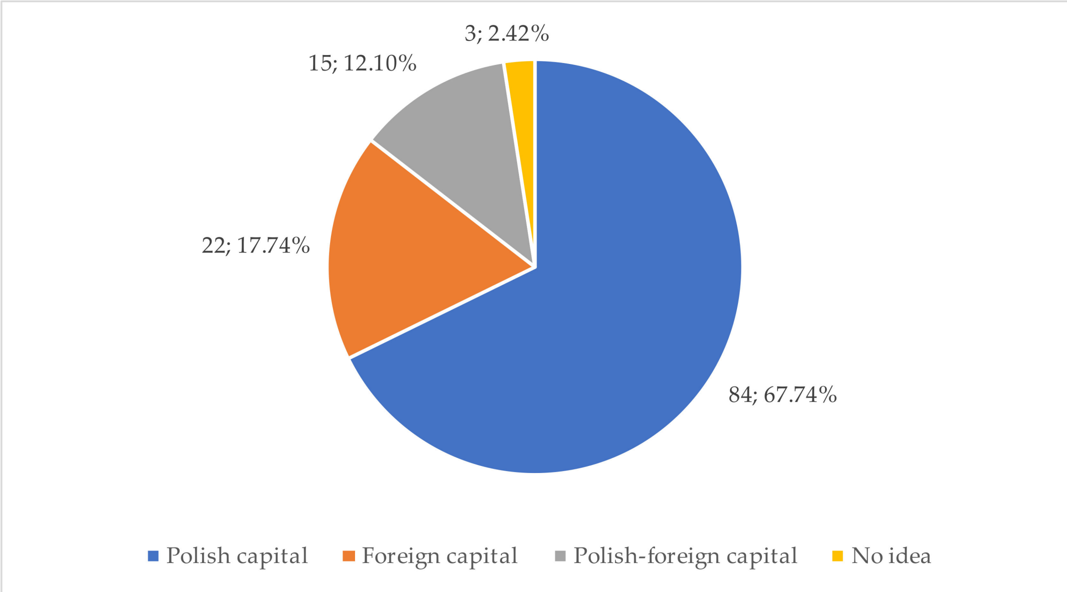

Figure 11. Company capital.

Nearly 59% of respondents participated in foreign projects. The use of BIM in Poland is rare; hence, projects performed by Polish engineers for foreign markets increase its use in the survey (Figure 12).

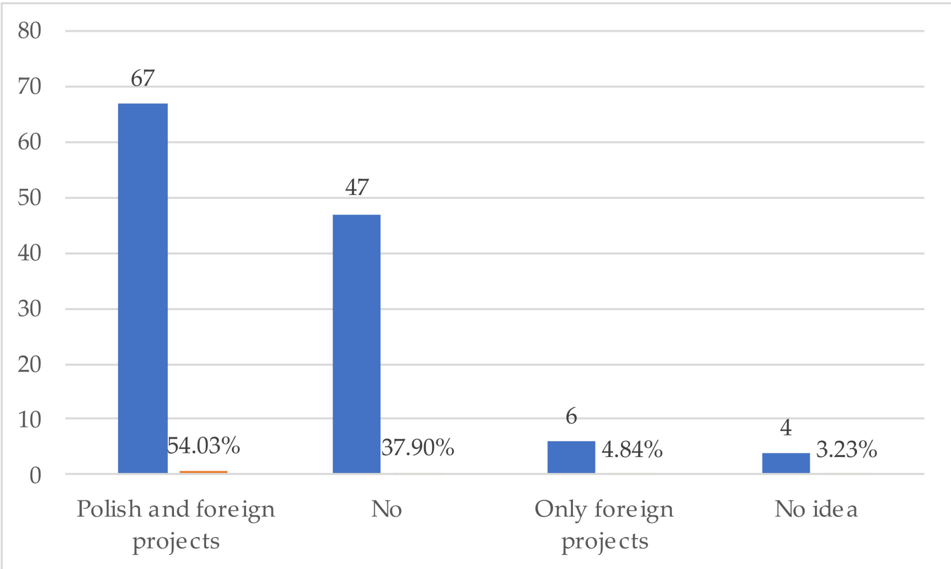

Figure 12. Participation in foreign projects.

This is how the experience with BIM at work is shaped. Experience using BIM coincides with participation in foreign projects, which confirms the rarity of BIM use in Poland (Figure 13).

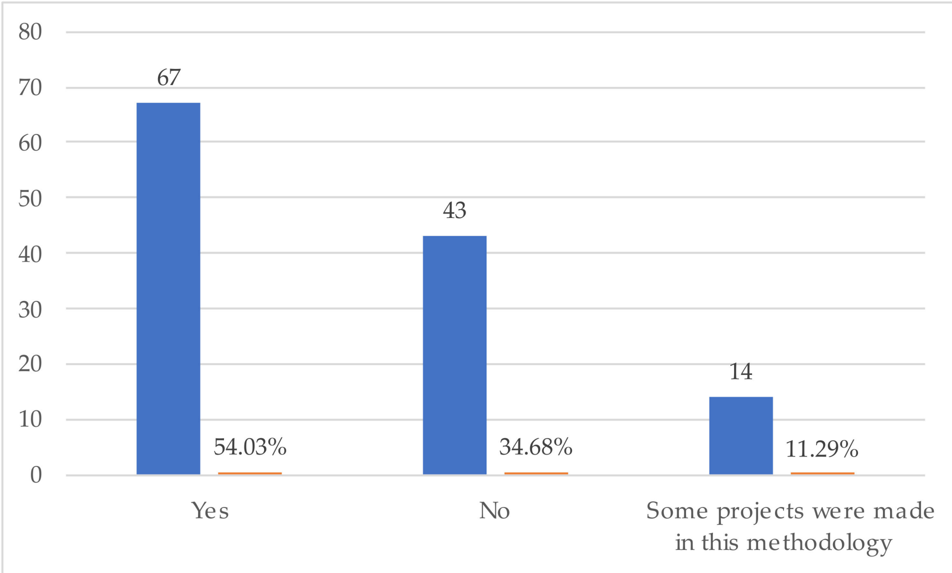

Figure 13. Work experience with BIM.

BIM in projects, 84 votes in favor of the need to use this methodology. This is certainly a positive aspect, where respondents demonstrate awareness of the advantages that BIM brings (Figure 14).

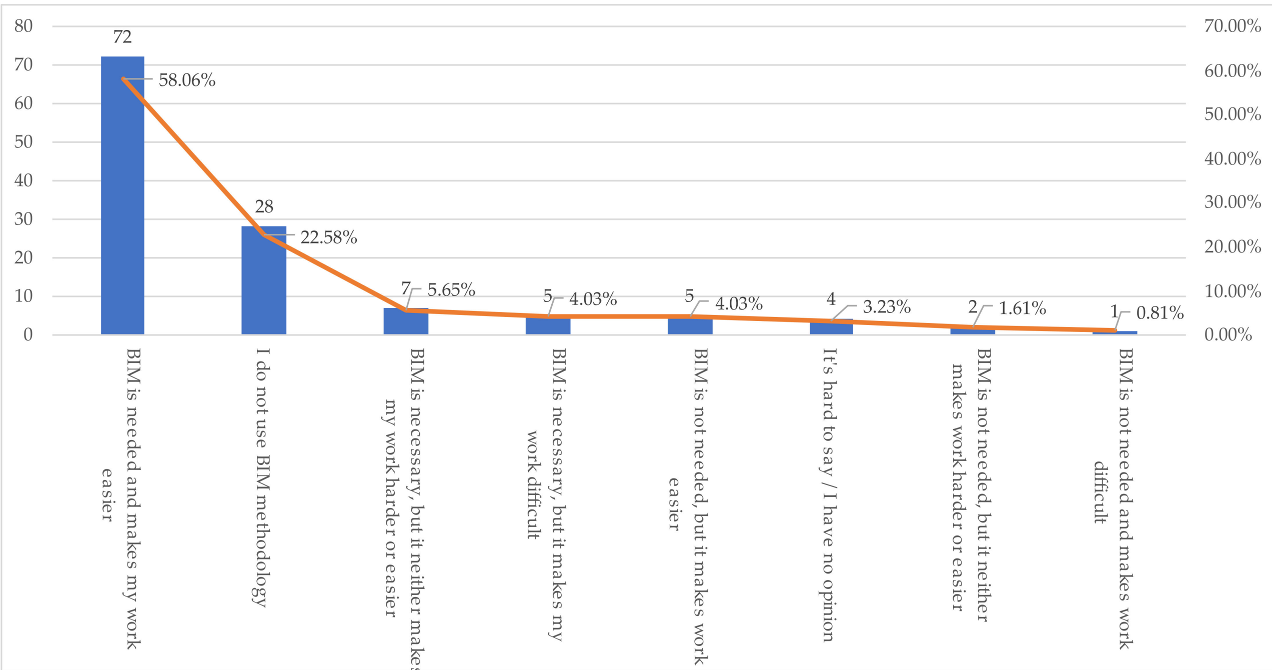

Figure 14. Opinions of respondents about the needs for using BIM.

Knowledge of software, Autodesk Revit is by far the most popular. What is very telling and puzzling is the fact that no one has pointed out any CDE platform. In this example, we can see what was included in the introduction of the article. Namely, that BIM for most people is a 3D model, not data (Figure 15).

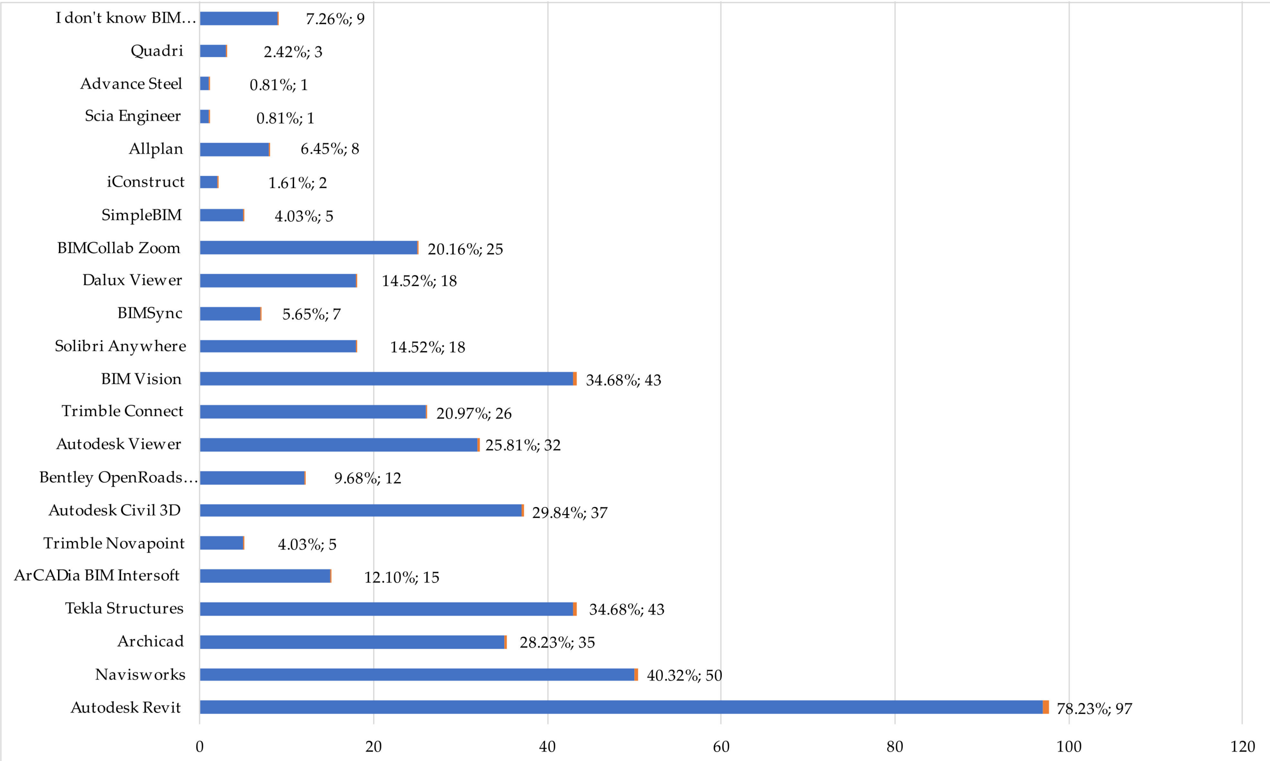

Figure 15. BIM software known by respondents.

The main purpose for which BIM is used by Polish engineers is to create models, detect collisions, and generate reports (Figure 16).

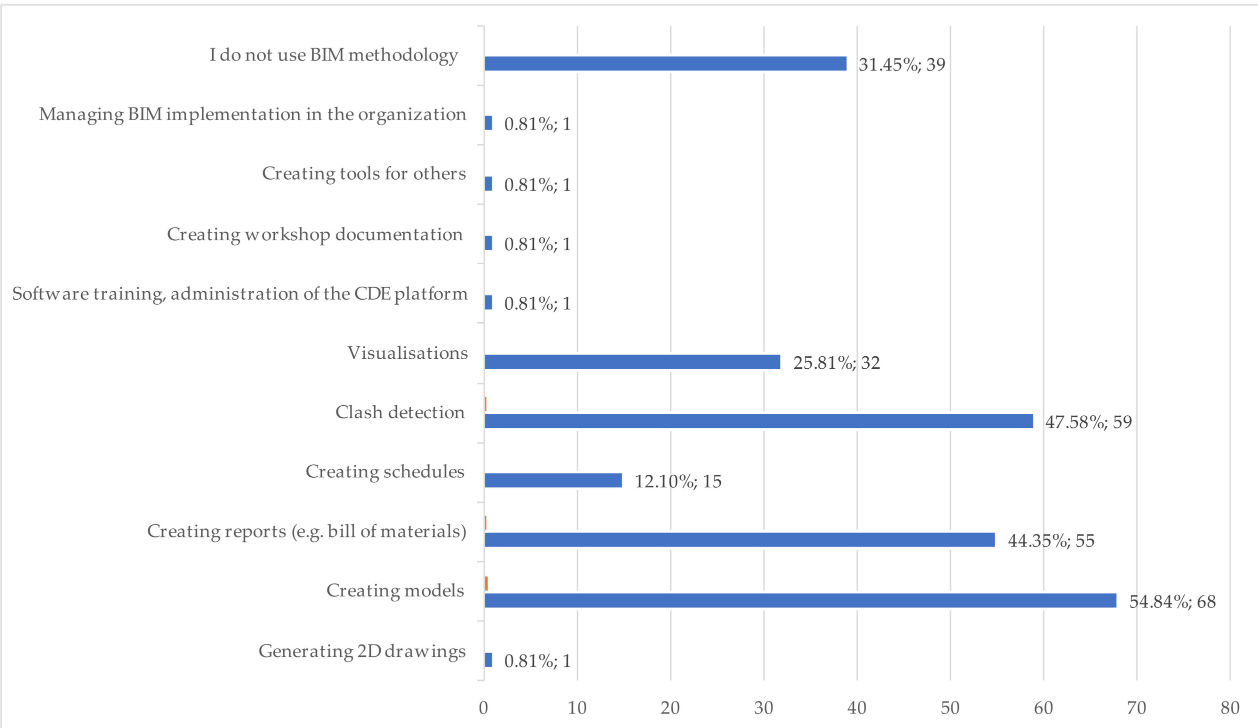

Figure 16. Use of BIM software by Polish engineers.

The use of standards from the ISO 19650 series by companies in Poland is very rare (Figure 17).

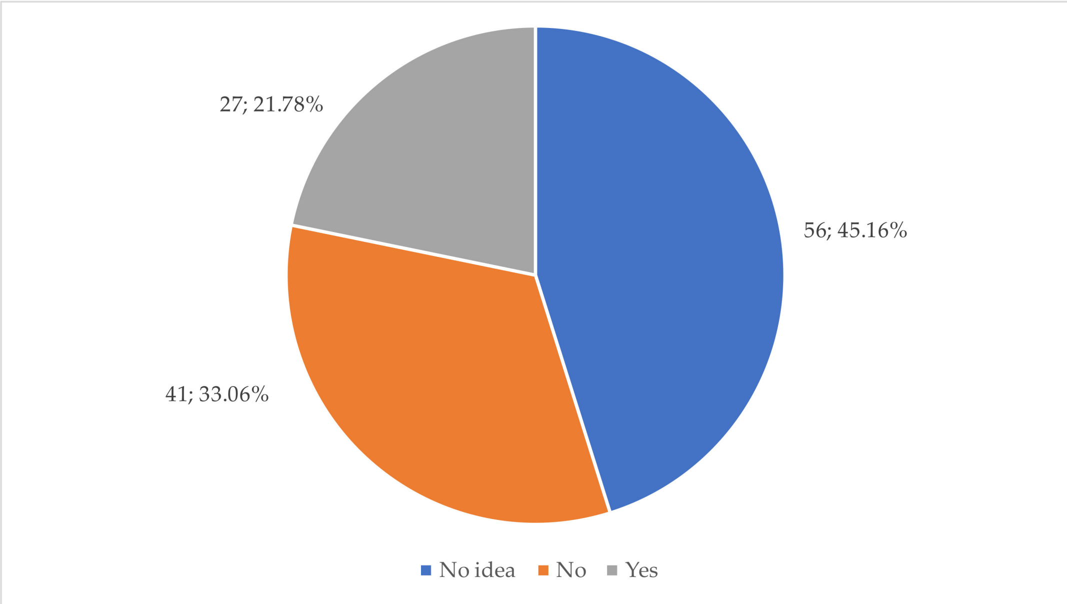

Figure 17. Using ISO 19650 standards in projects.

Modern technologies coexisting with BIM are even less frequently used (Figure 18).

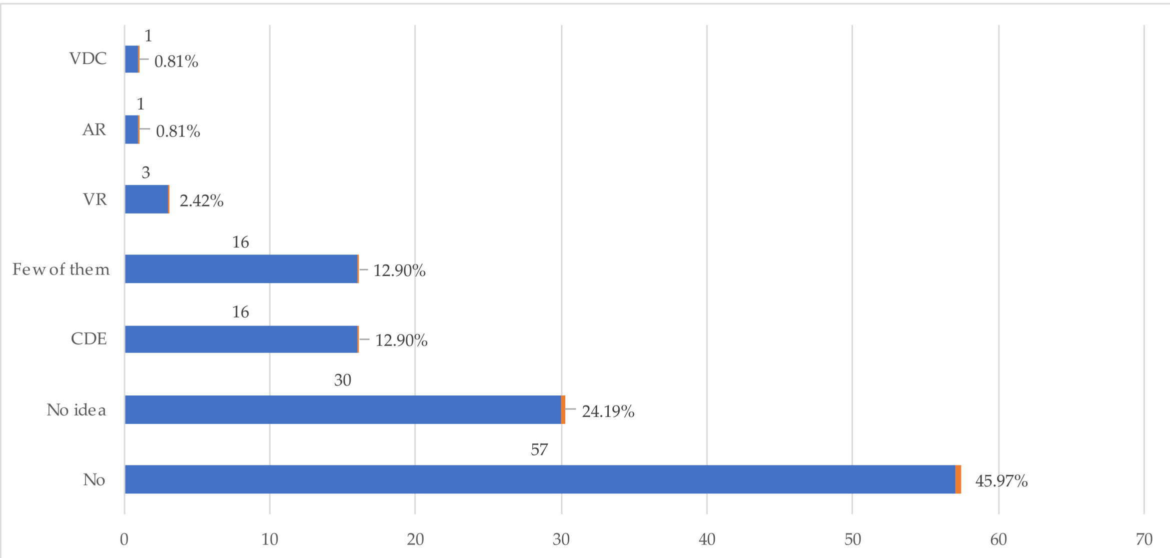

Figure 18. Applying co-existing technologies to BIM such as VR, AR, VDC, or CDE.

Over 62% of people believe that the use of BIM brings benefits in the form of improving the quality of projects (Figure 19).

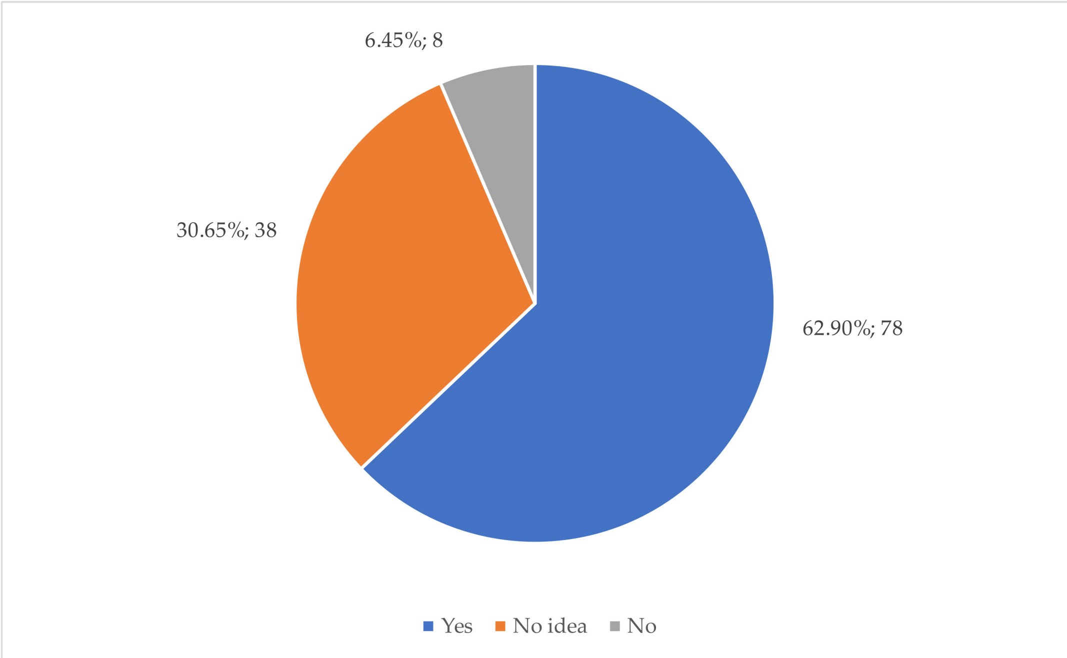

Figure 19. Computerization of the AEC industry brings benefits in the form of improvement in the quality of projects.

Benefits in the form of time and cost savings in project implementation are indicated by over 46% of respondents (Figure 20).

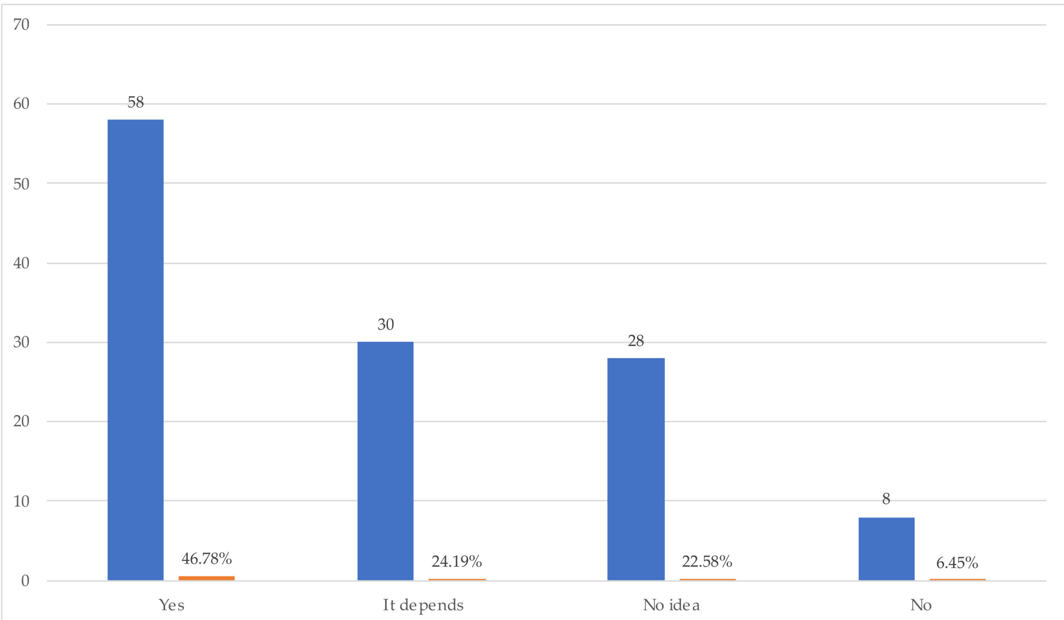

Figure 20. Computerization of the AEC industry brings benefits in the form of time and cost savings.

Implementing BIM in companies involves major challenges. The vast majority of respondents point to costs (48.39%), employee training, and lack of awareness of the need for computerization (50.81%) (Figure 21).

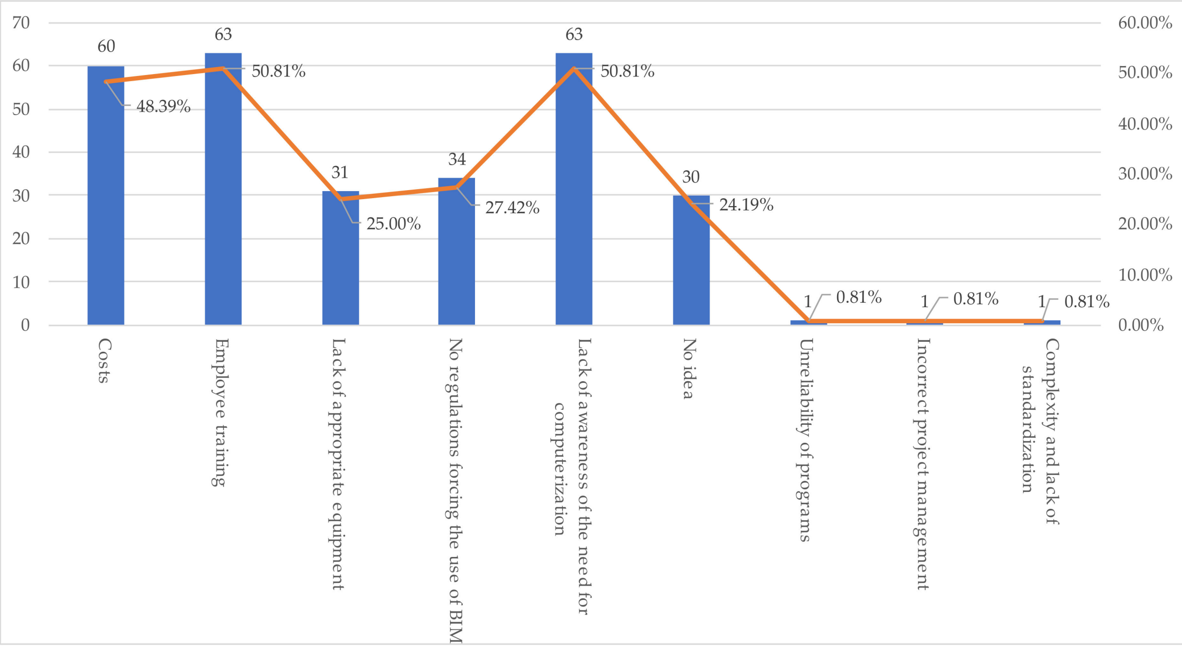

Figure 21. Challenges associated with implementing BIM in companies.

Opinions on the readiness of companies to implement modern information technologies. Many Polish companies are technologically backward, which is noticed by the employees themselves (Figure 22).

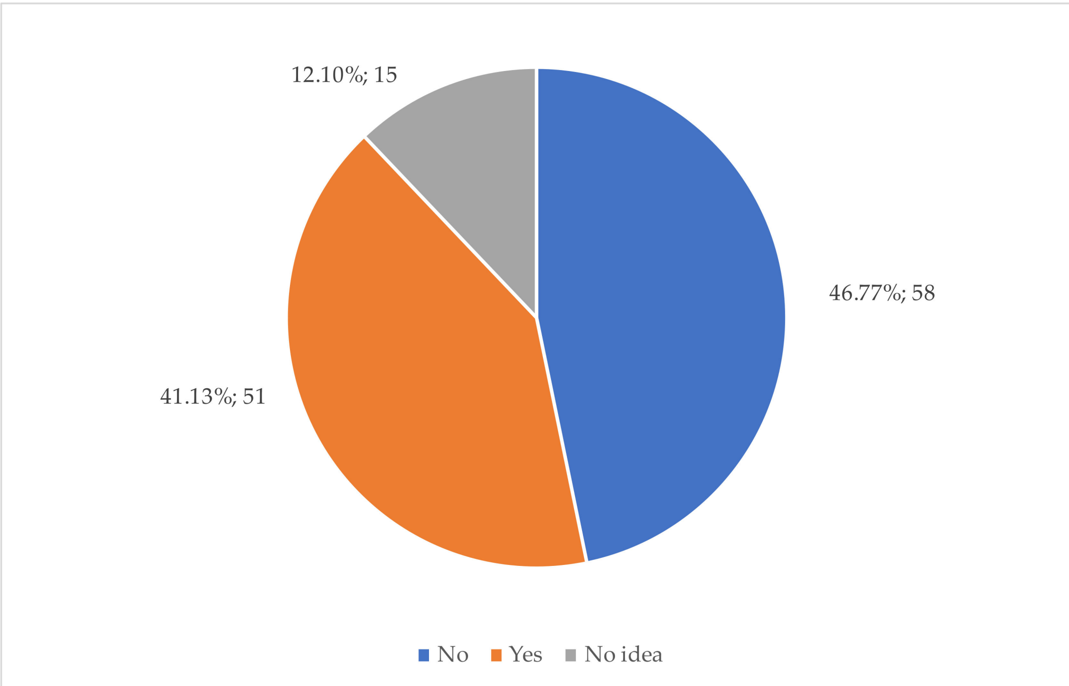

Figure 22. Opinions of respondents about the readiness of the companies in which they work to implement modern information technologies.

Polish companies definitely need training in the implementation of modern technologies. The results confirm the data presented above (Figure 23).

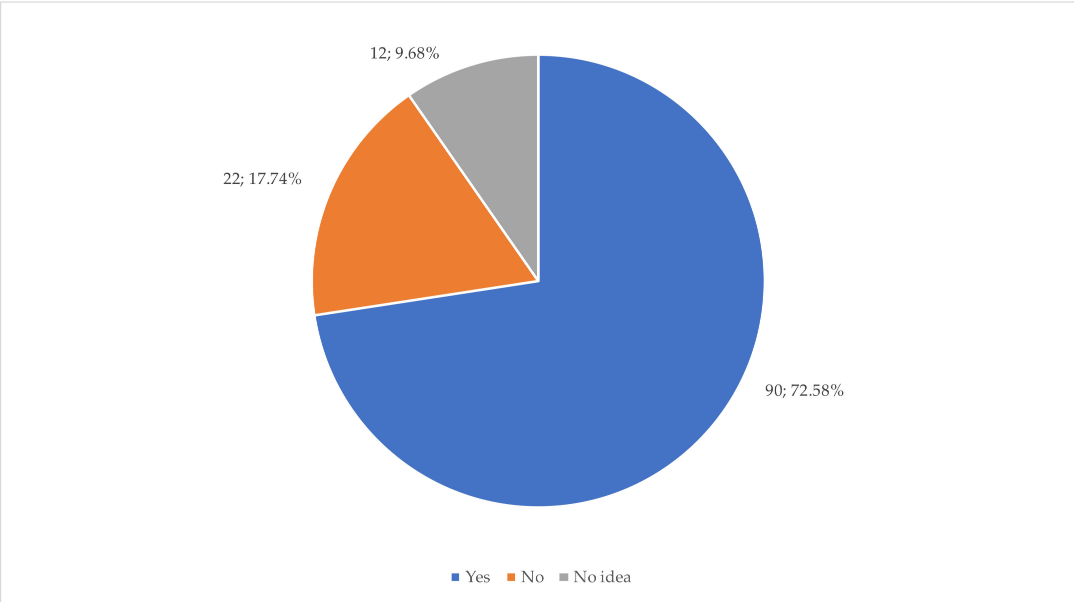

Figure 23. The demand for training in the implementation of modern technologies.

The penultimate question of the survey was: "Do you think that the AEC industry should invest in computerization and the development of modern technologies?" Over 77% of people support increasing investment in this sector (Figure 24).

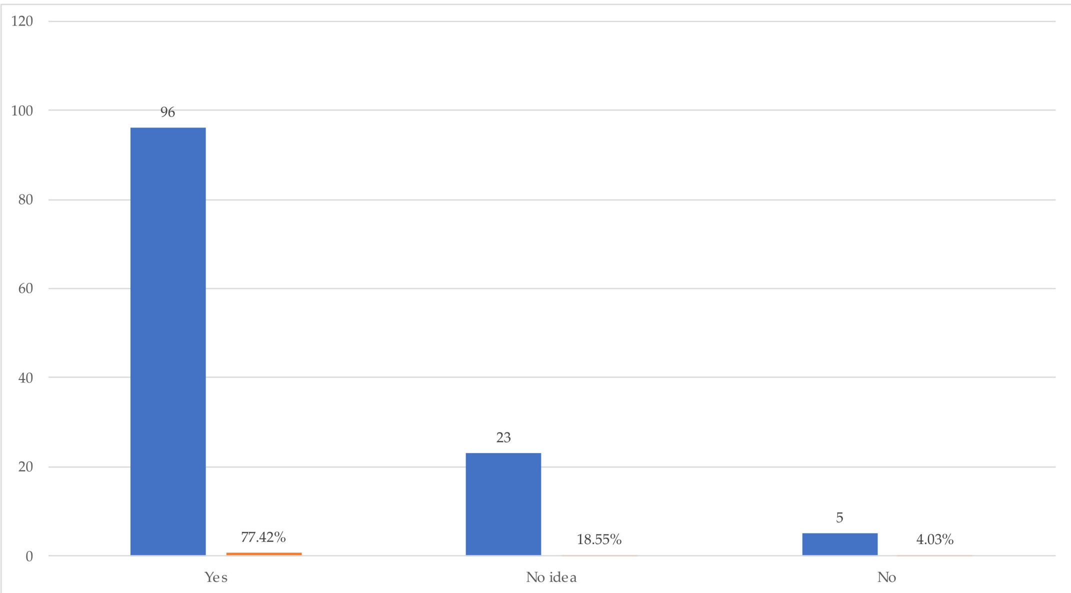

Figure 24. The AEC industry should invest in computerization and the development of modern technologies.

In the last question, the respondents were asked to choose their level of knowledge and awareness related to the application of BIM methodology. We can see relatively high results. They are inconsistent with previous answers to questions that largely exposed a lack of knowledge of modern technologies in the AEC industries (Figure 25).

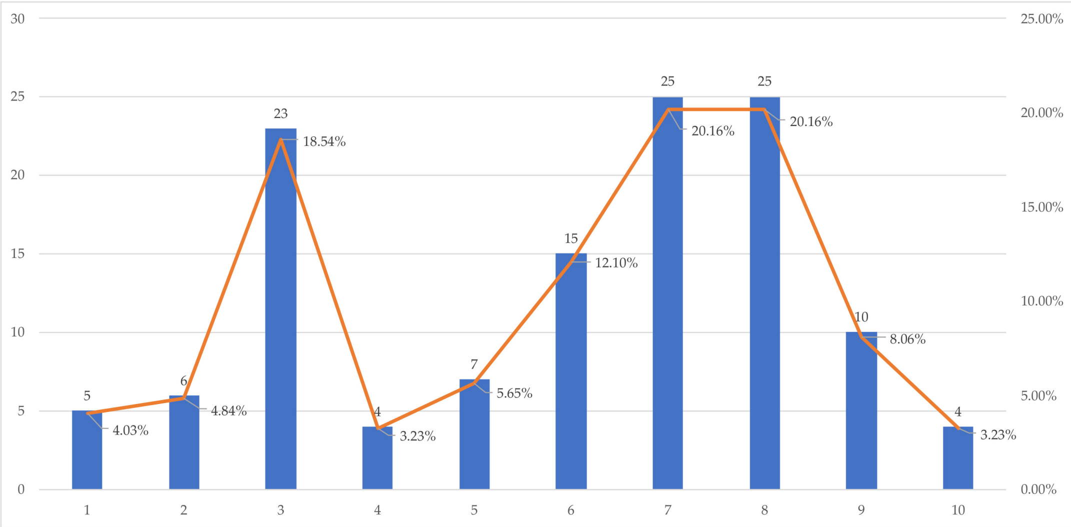

Figure 25. Opinions of respondents regarding their knowledge and awareness of the use of BIM methodology (where 1—no knowledge, 10—expert).

The survey results give serious thought to the state of BIM use, knowledge, and the need for digitization of the construction process in Poland. It can be stated with certainty that Polish engineers still have a lot to learn in this field. The study shows that over 34% of respondents do not use the BIM methodology at all, and the vast majority use BIM for creating models (54.84%) and generating reports (44.35%) or detecting collisions (47.58%). However, only 16 people (12.9%) indicated that they use the CDE platform, which de facto reflects the state of BIM in Poland, as its main idea is to use current and verified data. Also, over 29% of respondents do not see the benefits of computerization of the AEC industries. Opinions on BIM and the challenges associated with it are shaping up very similarly worldwide to those presented in the study below [53]. Understanding the essence of the need to introduce the requirement to use BIM in projects, problems with the implementation of new technologies by companies, analysis of models and data, and introduction and standardization of BIM standards are key to changing the digital landscape in the AEC industry not only in Poland but also worldwide [54]. All of this is crucial for the time and cost of investments conducted in this methodology [55]. BIM has a broad impact on construction stages, processes, data-based work culture, and sustainable environmental impact, which the authors proved in this article [56].

4. Discussion

The presented research results lead to reflection and discussion about expanding the knowledge and digital competencies of Polish engineers. It should be mentioned that it is only a matter of time before the legislator introduces the requirement to use BIM in public procurement. The previously mentioned United Kingdom and Norway are examples of how BIM is key to the effective design and implementation of large-scale construction investments, such as the Hinkley Point C [57] or Randselva Bridge [58]. We propose a strategy and framework that can help implement BIM in public procurement in Poland (Figure 26).

- Establishing BIM standards: The first step is to establish BIM standards that will be used throughout the country. These standards should be consistent with international standards, such as ISO 19650, but should also take into account the specifics of the Polish construction market [59].
- Training and education: It is important to provide appropriate training and education for all stakeholders, including designers, engineers, contractors, and property managers. This can include both formal courses and on-the-job training [60].

- Technological support: Implementing BIM requires appropriate technological support, including BIM software and computer hardware. This may also include the development of tools and technologies specific to Poland [61].
- Changing regulations: Implementing BIM in public procurement may require changes to existing regulations and procedures. For example, public procurement regulations may need to be modified to enable the use of BIM [62].
- Pilot and evaluation: It is recommended to conduct pilot projects to assess the effectiveness of BIM implementation and identify areas that require further development. The results of these pilot projects should then be used for continuous improvement of the implementation process [63].
- Collaboration and partnership: Implementing BIM is a complex and multi-faceted task that requires collaboration between various stakeholders. This may include partnerships between the public, private, and academic sectors [64].

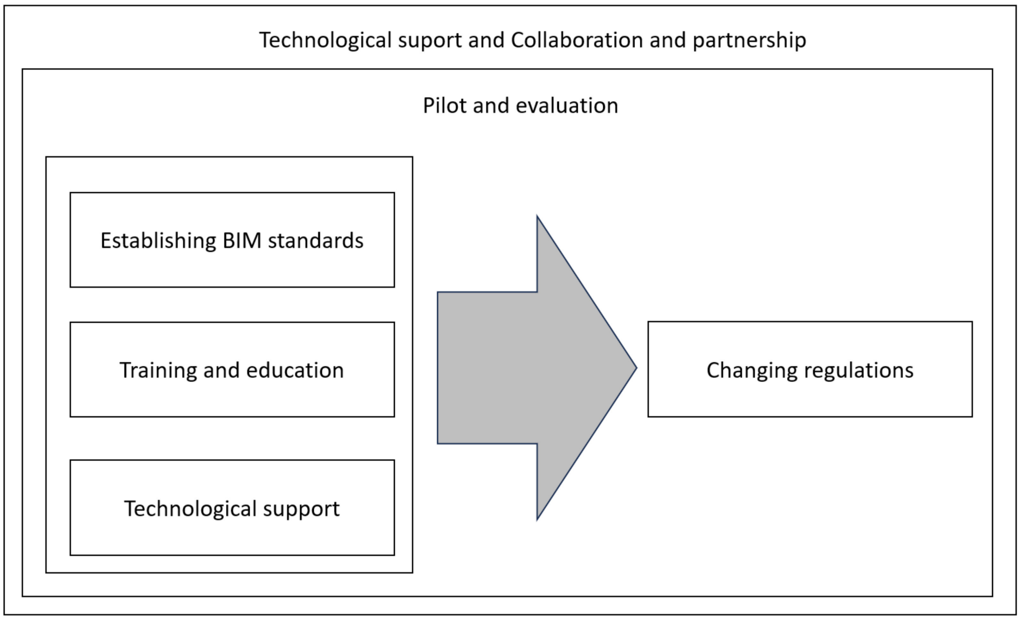

Figure 26. Recommended BIM implementation scheme.

BIM implementation should be based on the comprehensive activities presented above, where education and piloting combined with continuous evaluation are of paramount importance. In addition to the mechanisms shown, greater affordability (currently very expensive in Poland in terms of earnings) of appropriate software is also important [65].

The AEC industries are some of the most dispersed and complex industries in the world [66]. Collaboration among various participants in the construction process is often hindered by a lack of common data and information. Building information modeling (BIM) is an approach to design and construction that gathers all data about an object in one digital model. BIM has the potential to streamline collaboration among participants in the construction process, improve project quality, and reduce costs. The article "Digitization of AEC industries based on BIM and 4.0 technologies" discusses the impact of BIM methodology on the construction industry in the context of the fourth industrial revolution, known as Industry 4.0.

The BIM methodology is an essential part of this revolution, enabling the digitization of construction processes and the management of complex objects such as industrial facilities, office buildings, infrastructure, etc. BIM is becoming increasingly popular in Poland, and more and more investors, both public and private, are deciding to use it in planned and implemented construction investments. Great examples on the side of Polish state-owned companies are the Polish State Railways [67] or the Central Communication Port [68], and the largest non-state companies on the Central European market, Budimex [69], Strabag [70], or Porr [71], have been implementing BIM in their projects for years.

The limitations of this study are the relatively small number of respondents—124. However, the questions were constructed in such a way as to conduct the analysis of the collected responses as objectively as possible. This was successful, as the results coincide with the research of other scientists. In the next publication, the authors want to verify the implementation of the BIM methodology—the challenges and obstacles associated with it on the largest infrastructure project in Europe—Central Communication Port (CPK). It will be a very complex and interesting publication, and the source materials and information will come directly from the company where one of the authors of this article works—Karol Zawada, as a BIM specialist.

5. Conclusions

In this article, it is emphasized that BIM brings great benefits and is becoming a standard in global construction. This is the entry into the era of digital construction, which can be compared to deep changes in industrial companies related to their digitization in the concept of Industry 4.0. [72]. The study indicated that a kind of revolution is taking place related to the principles of designing technological elements in construction. The recommendations presented in the discussion refer directly to the demands related to the further development of BIM in Poland. In the context of these observations, the conclusions drawn from the article are as follows: BIM has the potential to transform the AEC industries, bringing benefits to both investors and contractors. However, to fully utilize them, further training and education in BIM are necessary, as well as the introduction of appropriate legal regulations and the implementation of BIM procedures in construction companies [73]. It is worth mentioning that to fully and correctly implement this methodology and benefit from it, one should strictly base it on the standards from the ISO 19650 series [74]. In the future, BIM may not only become a standard but also a requirement in Polish construction.

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Glossary

4.0 technologies	Often referred to as "Industry 4.0", is a term that encapsulates the fourth industrial revolution. It represents a new phase in the industrial revolution that focuses heavily on interconnectivity, automation, machine learning, and real-time data. Industry 4.0 technologies integrate physical production and operations with smart digital technology, machine learning, and big data to create a more holistic and better-connected ecosystem for companies that focus on manufacturing and supply chain management. This technological evolution has the potential to reshape industries and redefine how businesses operate, create products, and serve their customers.
AEC	Stands for architecture, engineering, and construction. It is an industry that focuses on the design, engineering, and construction of buildings, infrastructure, and other physical structures. The AEC industry covers a wide range of services dedicated to the planning and construction of both commercial, infrastructural, and residential initiatives.

AI	Artificial intelligence is a field of computer science that aims to create systems capable of performing tasks that would normally require human intelligence. These tasks include learning from experience, understanding natural language, recognizing patterns, solving problems, and making decisions.
AR	Augmented reality is a technology that overlays digital information onto the real world, enhancing our perception of our surroundings. It creates an interactive experience by combining the real world with computer-generated content, which can include visual, auditory, haptic, and other sensory modalities.
BEP	Stands for BIM execution plan. It is a document that outlines how the "Information Modeling" part of a project will be executed. The BEP is central to the BIM process and is prepared to streamline the management of information in a BIM project. It details the project deliverables estimated by the contract and the information exchange protocol and requirements. The BEP is developed in response to the EIR and is shared with all stakeholders involved in the project.
Big Data	Is a term that describes large volumes of data, both structured and unstructured. It is not the amount of data that is important, but what organizations do with it. Big data can be analyzed for insights that lead to better decisions and strategic business moves. The primary goal of big data analytics is to help companies make more informed business decisions by enabling data scientists and other users to analyze huge volumes of data that may be left untapped by conventional business intelligence (BI) programs.
BIM	Building information modeling is a digital representation of the physical and functional characteristics of a building or other physical asset. It is a process that involves generating and managing this digital information throughout the lifecycle of the building, from planning and design to construction and operations. BIM integrates structured, multi-disciplinary data to produce a comprehensive model of an asset. This technology is used in the architecture, engineering, and construction (AEC) industry to improve collaboration, increase efficiency, and enable better decision making. It is a key component of the digital transformation in the AEC industry.
CDE	Common data environment is a digital platform that serves as a single source of information used to collect, manage, and disseminate documentation, graphical models, and non-graphical data for an entire project team. It is a key component of BIM workflows, facilitating collaboration between project team members and helping to avoid files duplication and designing mistakes. The CDE can include a wide range of information, from project contracts and schedules to change orders. It is designed to improve the creation, sharing, and issuing of information that underpins the delivery of a project. By providing a central hub for project information, a CDE can enhance efficiency, reduce errors, and support better decision making.
Data Science	Is an interdisciplinary field that uses scientific methods, processes, algorithms, and systems to extract knowledge and insights from structured and unstructured data. It involves techniques and theories drawn from many fields within the context of mathematics, statistics, and computer science. Data scientists use their skills in both technology and social science to find trends and manage data. They use industry knowledge, contextual understanding, skepticism of existing assumptions, and analytical skills to uncover solutions to business challenges. It is a rapidly evolving field with applications in numerous industries, from healthcare to finance to marketing and beyond.

EIR	Stands for exchange information requirements. It is a document drawn up by the client defining all the requirements related to the information exchanges of a BIM process. The EIR is a pre-tender document that defines standards, information, and requirements of a BIM process and constitutes the initial input of the tender process. It focuses on the methods to be performed for the sharing of data and the generation of documents, focusing on the management of information content among the various stakeholders. The EIR forms a text type document in which the reference regulatory aspects, priorities, objectives, and models to be implemented for each design phase with levels of information appropriate to the reference step are identified.
ESG	Stands for environmental, social, and governance. It is a framework used by investors and other stakeholders to evaluate the sustainability and societal impact of an organization. The "Environmental" aspect considers how a company performs as a steward of the natural environment. The "Social" aspect examines how a company manages relationships with its employees, suppliers, customers, and the communities where it operates. The "Governance" aspect involves a company's leadership, executive pay, audits, internal controls, and shareholder rights.
ISO 19650	Is an international standard for managing information throughout the lifecycle of a construction project using BIM. It encompasses the organization and digitization of information about buildings and civil engineering works. The standard includes the same high-level principles and requirements as BIM Level 2. It was developed by the International Organization for Standardization's Technical Committee ISO/TC 59, Buildings and civil engineering works, SC 13. The standard is based on the older British Standard PAS 1192, but introduces some new concepts.
LOD	Level of development is a framework used in the AEC industry to define and articulate the content and reliability of BIM at different stages of design and construction. It was first introduced by the American Institute of Architects (AIA) in 2008. The LOD specification helps professionals in the industry to communicate how an element's geometry and associated information has evolved throughout the entire process. It signifies the degree to which different members of the team can rely on information associated with an element. Currently, there are six levels of development, from LOD 100 to LOD 500, each representing a different stage of element detail and information accuracy.
LOG	Stands for level of geometry. It is a part of the LOD concept, which also includes LOI. The LOG in a BIM model expresses the geometric level of detail. For example, EMCS 4.0 distinguishes between 5 different levels, where LOG 1 stands for a schematic or symbolic representation of a product, and LOG 5 for a detailed, manufacturer-specific representation. It tells us something about the appearance (the geometry) of the element.
LOI	Stands for level of information. It is a part of the LOD concept, which also includes LOG. The LOI in a BIM model represents the non-geometric, technical information of a model. For example, content with a high LOI contains manufacturer-specific information such as price, volume, and materials.
Point clouds	Represent a collection of data points in three-dimensional space. These points are captured using 3D laser scanners, and they record the precise geometry and spatial information of an area or object. The point cloud data can then be imported into BIM software, where it can be visualized and modeled. This process allows for an accurate as-built representation of a building or space. Point clouds are crucial in BIM as they provide a detailed and accurate foundation for creating comprehensive BIM models.
VDC	Stands for virtual design and construction. It is the management of integrated multi-disciplinary performance models of design-construction projects, including the product (facilities), work processes, and organization of the design-construction-operation team. The goal of VDC is to support explicit and public business objectives. It involves building the project once digitally to work out the big problems, then building it more efficiently in the physical world.

VR	Virtual reality is a technology that creates a simulated experience by employing 3D near-eye displays and pose tracking. It immerses the user in a computer-generated environment that simulates reality. VR applications range from entertainment, particularly video games, to education such as medical, safety or military training, and business such as virtual meetings. The user can interact with the virtual world using VR equipment, such as headsets or gloves, which provide visual, auditory, and sometimes haptic feedback. The term "virtual reality" was coined in 1987 by Jaron Lanier, who contributed significantly to the early development of VR technology.

References

1. Anger, A.; Łaguna, P.; Zamara, B. *BIM Dla Managerów*; BIM.; PWN: Warszawa, Poland, 2021; ISBN 978-83-01-21393-0.
2. Buchanan, E.; Loporcaro, G.; Lukosch, S. On the Effectiveness of Using Virtual Reality to View BIM Metadata in Architectural Design Reviews for Healthcare. *Multimodal Technol. Interact.* **2023**, *7*, 60. [CrossRef]
3. Alnaser, A.A.; Alsanabani, N.M.; Al-Gahtani, K.S. BIM Impact on Construction Project Time Using System Dynamics in Saudi Arabia's Construction. *Buildings* **2023**, *13*, 2267. [CrossRef]
4. *BS EN ISO 19650-1:2018*; Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM). Information Management Using Building Information Modelling Concepts and Principles. British Standards Institution: London, UK, 2019; Volume 1, ISBN 978-0-580-92466-8.
5. *BS EN ISO 19650-2:2018*; Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM). Information Management Using Building Information Modelling Delivery Phase of the Assets. British Standards Institution: London, UK, 2021; Volume 2, ISBN 978-0-539-13892-4.
6. *BS EN ISO 19650-3:2020*; Organization and Digitization of Information About Buildings and Civil Engineering Works, Including Building Information Modelling (BIM)—Information Management Using Building Information Modelling. British Standards Institution: London, UK, 2020; Volume 3, ISBN 978-0-539-00172-3.
7. *BS EN ISO 19650-4:2022*; Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM). Information Management Using Building Information Modelling Information Exchange. British Standards Institution: London, UK, 2023; Volume 4, ISBN 978-0-539-28410-2.
8. *BS EN ISO 19650-5:2020*; Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM). Information Management Using Building Information Modelling. Security-Minded Approach to Information Management. British Standards Institution: London, UK, 2020; Volume 5, ISBN 978-0-539-01039-8.
9. Nalepka, M.; Mrozek, R. Zalety i wady technologii BIM. *Builder* **2017**, *239*, 118–123.
10. Panya, D.S.; Kim, T.; Choo, S. An Interactive Design Change Methodology Using a BIM-Based Virtual Reality and Augmented Reality. *J. Build. Eng.* **2023**, *68*, 106030. [CrossRef]
11. Wang, Q.; Li, J.; Tang, X.; Zhang, X. How Data Quality Affects Model Quality in Scan-to-BIM: A Case Study of MEP Scenes. *Autom. Constr.* **2022**, *144*, 104598. [CrossRef]
12. Rane, N. Integrating Building Information Modelling (BIM) and Artificial Intelligence (AI) for Smart Construction Schedule, Cost, Quality, and Safety Management: Challenges and Opportunities. *SSRN Electron. J.* **2023**. [CrossRef]
13. Salamak, M. *BIM w Cyklu Życia Mostów*; Wydawnictwo Naukowe PWN: Warszawa, Poland, 2021; ISBN 978-83-01-21364-0.
14. Turk, Ž.; Sonkor, M.S.; Klinc, R. Cybersecurity assessment of BIM/CDE design environment using cyber assessment framework. *J. Civ. Eng. Manag.* **2022**, *28*, 349–364. [CrossRef]
15. Prochowska, O.; Jędrosz, W. SDGs vs. ESG i Jak BIM Może Pomóc w Osiągnięciu Zrównoważonych Celów. Available online: https://g4bim.pl/sdgs-vs-esg-i-jak-bim-moze-pomoc-w-osiagnieciu-zrownowazonych-celow (accessed on 14 April 2024).
16. Zima, K.; Plebankiewicz, E.; Wieczorek, D. A SWOT Analysis of the Use of BIM Technology in the Polish Construction Industry. *Buildings* **2020**, *10*, 16. [CrossRef]
17. Eadie, R.; Odeyinka, H.; Browne, M.; Mahon, C.; Yohanis, M. Building Information Modelling Adoption: An Analysis of the Barriers to Implementation. *J. Eng. Archit.* **2014**, *2*, 77–101.
18. BIM w Polsce. Available online: https://www.gov.pl/web/rozwoj-technologia/bim-w-polsce (accessed on 16 April 2024).
19. Mitera-Kiełbasa, E.; Zima, K. BIM Policy in Eastern Europe. *Civ. Environ. Eng. Rep.* **2024**, *33*, 14–22. [CrossRef]
20. *Dziennik Urzędowy Ministra Rozwoju i Technologii, Poz. 7, Zarządzenie Nr 6 z Dnia 4 Marca 2022 r. w Sprawie Powołania Grupy Roboczej Do Spraw BIM*; Dziennik Urzędowy Ministra Rozwoju i Technologii: Warsaw, Poland, 2022.
21. Edirisinghe, R.; London, K. Comparative Analysis of International and National Level BIM Standardization Efforts and BIM Adoption. In Proceedings of the 32nd CIB W78 Conference, Eindhoven, The Netherlands, 26 April 2016; pp. 149–158.
22. Ganah, A.; Lea, G. A global analysis of bim standards across the globe: A critical review. *J. Proj. Manag. Pract.* **2021**, *1*, 52–60. [CrossRef]
23. Liu, Z.; Chi, Z.; Osmani, M.; Demian, P. Blockchain and Building Information Management (BIM) for Sustainable Building Development within the Context of Smart Cities. *Sustainability* **2021**, *13*, 2090. [CrossRef]
24. Kaewunruen, S.; Sresakoolchai, J.; Zhou, Z. Sustainability-Based Lifecycle Management for Bridge Infrastructure Using 6D BIM. *Sustainability* **2020**, *12*, 2436. [CrossRef]

25. Doan, D.T.; Ghaffarianhoseini, A.; Naismith, N.; Zhang, T.; Rehman, A.U.; Tookey, J.; Ghaffarianhoseini, A. What Is BIM? A Need for A Unique BIM Definition. *MATEC Web Conf.* **2019**, *266*, 05005. [CrossRef]
26. Wang, H.; Lin, Y.; Gan, X. Advantages and Development Prospects of Building Information Modelling (BIM) Technology Application in Highway Engineering. *J. Archit. Res. Dev.* **2023**, *7*, 1–5. [CrossRef]
27. Sytuacja Społeczno-Gospodarcza Kraju w Pierwszym Kwartale 2023 r. Available online: https://stat.gov.pl/obszary-tematyczne/inne-opracowania/informacje-o-sytuacji-spoleczno-gospodarczej/sytuacja-spoleczno-gospodarcza-kraju-w-pierwszym-kwartale-2023-r-,1,131.html (accessed on 28 December 2023).
28. Orlińska-Dejer, K. BIM w Przetargach Publicznych—Analiza Wybranych Postępowań Przetargowych. *Mater. Bud.* **2017**, *1*, 139–141. [CrossRef]
29. *BS 1192:2007+A2:2016*; Collaborative Production of Architectural, Engineering and Construction Information—Code of Practice. British Standards Institution: London, UK, 2008; ISBN 978-0-580-92817-8.
30. *BS 7000-4:2013*; Design Management Systems. Guide to Managing Design in Construction. British Standards Institution: London, UK, 2013; ISBN 978-0-580-88382-8.
31. *BS 8541-1:2012*; Library Objects for Architecture, Engineering and Construction Identification and Classification. Code of Practice. British Standards Institution: London, UK, 2012; ISBN 978-0-580-74144-9.
32. *BS 8541-2:2011*; Library Objects for Architecture, Engineering and Construction Recommended 2D Symbols of Building Elements for Use in Building Information Modelling. British Standards Institution: London, UK, 2011; ISBN 978-0-580-77126-2.
33. *BS 8541-3:2012*; Library Objects for Architecture, Engineering and Construction—Part 3: Shape and Measurement—Code of Practice. British Standards Institution: London, UK, 2012; ISBN 978-0-580-74145-6.
34. *BS 8541-4:2012*; Library Objects for Architecture, Engineering and Construction—Attributes for Specification and Assessment. Code of Practice. British Standards Institution: London, UK, 2012; ISBN 978-0-580-74146-3.
35. *PAS 1192-2:2013*; Specification for Information Management for the Capital/Delivery Phase of Construction Projects Using Building Information Modelling. British Standards Institution: London, UK, 2013; ISBN 978-0-580-78136-0.
36. *PAS 1192-3:2014*; Specification for Information Management for the Operational Phase of Assets Using Building Information Modelling. British Standards Institution: London, UK, 2014; ISBN 978-0-580-86674-6.
37. Tomczak, A.; Berlo, L.V.; Krijnen, T.; Borrmann, A.; Bolpagni, M. A Review of Methods to Specify Information Requirements in Digital Construction Projects. *IOP Conf. Ser. Earth Environ. Sci.* **2022**, *1101*, 092024. [CrossRef]
38. Altwassi, E.J.; Aysu, E.; Ercoskun, K.; Abu Raed, A. From Design to Management: Exploring BIM's Role across Project Lifecycles, Dimensions, Data, and Uses, with Emphasis on Facility Management. *Buildings* **2024**, *14*, 611. [CrossRef]
39. Karlapudi, J.; Valluru, P.; Menzel, K. Ontological Approach for LOD-Sensitive BIM-Data Management. In Proceedings of the 9th Linked Data in Architecture and Construction Workshop, Luxembourg, 11–13 October 2021. [CrossRef]
40. Van Der Vaart, J.; Stoter, J.; Diakité, A.; Biljecki, F.; Ohori, K.A.; Hakim, A. Assessment of the LoD Specification for the Integration of BIM-Derived Building Models in 3D City Models. In *Recent Advances in 3D Geoinformation Science*; Kolbe, T.H., Donaubauer, A., Beil, C., Eds.; Lecture Notes in Geoinformation and Cartography; Springer Nature: Cham, Switzerland, 2024; pp. 171–191. ISBN 978-3-031-43698-7.
41. Carruthers, C.; Jackson, P. *Halo Data: Understanding and Leveraging the Value of Your Data*, 1st ed.; Facet: London, UK, 2023; ISBN 978-1-78330-618-3.
42. Balin, S.; Bolognesi, C.M.; Borin, P. Integration of Immersive Approaches for Collaborative Processes with Building Information Modeling (BIM) Methodology for the AEC Industry: An Analysis of the Current State and Future Challenges. *Virtual Worlds* **2023**, *2*, 374–395. [CrossRef]
43. Borkowski, A.S.; Brożyna, J.; Litwin, J.; Rączka, W.; Szporanowicz, A. Use of the cde environment in team collaboration in BIM. *Inform. Autom. Pomiary W Gospod. Ochr. Śr.* **2023**, *13*, 93–98. [CrossRef]
44. Godager, B.; Mohn, K.; Merschbrock, C.; Klakegg, O.J.; Huang, L. Towards an Improved Framework for Enterprise BIM: The Role of ISO 19650. *J. Inf. Technol. Constr.* **2022**, *27*, 1075–1103. [CrossRef]
45. Jaskula, K.; Papadonikolaki, E.; Rovas, D. Comparison of Current Common Data Environment Tools in the Construction Industry. In Proceedings of the 2023 European Conference on Computing in Construction 40th International CIB W78 Conference, Heraklion, Crete, Greece, 10–12 July 2023.
46. Sun, Z. Big Data 4.0: The Era of Big Intelligence. *J. Comput. Sci. Res.* **2024**, *6*, 1–15. [CrossRef]
47. Thorat, R.V. Rajendra Kumar Vilas Thorat Role of Mathematics in Data Science-Machine Learning. *Int. J. Sci. Res. Mod. Sci. Technol.* **2024**, *3*, 18–21. [CrossRef]
48. Yin, H. Innovation and Exploration of Construction Project Management Based on BIM Platform of Big Data. *Appl. Math. Nonlinear Sci.* **2024**, *9*, 20230445. [CrossRef]
49. Piazzai, R. AI and BIM Integration: Redefining Efficiency and Opportunities in the AEC Industry. Available online: https://business.bimobject.com/blog/redefining-efficiency-and-opportunities-in-the-aec-industry/ (accessed on 14 April 2024).
50. Rane, N.; Choudhary, S.; Rane, J. Integrating Building Information Modelling (BIM) with ChatGPT, Bard, and Similar Generative Artificial Intelligence in the Architecture, Engineering, and Construction Industry: Applications, a Novel Framework, Challenges, and Future Scope. *SSRN Electron. J.* **2023**. [CrossRef]
51. He, Z.; Wang, Y.-H.; Zhang, J. Generative Structural Design Integrating BIM and Diffusion Model. *arXiv* **2023**, arXiv:2311.04052. [CrossRef]

52. Nys, W. Artificial Intelligence in BIM and Renovation. Available online: https://www.buildingsmart.org/artificial-intelligence-in-bim-and-renovation/ (accessed on 14 April 2024).
53. Tahseen, M.A.; Hassan, T.M.; Bassioni, H.; Blay, K.B. CMBAS Tool for Assessing BIM Adoption Status in Construction Markets: Application for Egypt. *Buildings* **2023**, *13*, 2475. [CrossRef]
54. Aftab, U.; Jaleel, F.; Mansoor, R.; Haroon, M.; Aslam, M. Obstructions in BIM Implementation for Developing Countries—A Mini-Review. *Eng. Proc.* **2023**, *45*, 26. [CrossRef]
55. Musharavati, F. Optimized Integration of Lean Construction, Building Information Modeling, and Facilities Management in Developing Countries: A Case of Qatar. *Buildings* **2023**, *13*, 3051. [CrossRef]
56. Junussova, T.; Nadeem, A.; Kim, J.R.; Azhar, S. Key Drivers for BIM-Enabled Materials Management: Insights for a Sustainable Environment. *Buildings* **2023**, *14*, 84. [CrossRef]
57. Price, J.; Keppo, I.; Dodds, P.E. The Role of New Nuclear Power in the UK's Net-Zero Emissions Energy System. *Energy* **2023**, *262*, 125450. [CrossRef]
58. Wojsław, K.; Salamak, M. Most Randselva–Zaprojektowany i Zbudowany Bez Papierowych Rysunków. *Nowocz. Bud. Inż.* **2021**, *6*, 116–118.
59. BIM, Współpraca, Zarządzanie Informacją w Polskim Budownictwie. Available online: https://www.autodesk.pl/campaigns/raportbim (accessed on 16 April 2024).
60. Leśniak, A.; Górka, M.; Skrzypczak, I. Barriers to BIM Implementation in Architecture, Construction, and Engineering Projects—The Polish Study. *Energies* **2021**, *14*, 2090. [CrossRef]
61. BIM–Polska Perspektywa. Raport z Badania. Available online: https://damassets.autodesk.net/content/dam/autodesk/www/campaigns/bim-event/BIM_raport_final.pdf (accessed on 16 April 2024).
62. Ratajczak, J.; Riedl, M.; Matt, D. BIM-Based and AR Application Combined with Location-Based Management System for the Improvement of the Construction Performance. *Buildings* **2019**, *9*, 118. [CrossRef]
63. Potrč Obrecht, T.; Röck, M.; Hoxha, E.; Passer, A. BIM and LCA Integration: A Systematic Literature Review. *Sustainability* **2020**, *12*, 5534. [CrossRef]
64. Bonomolo, M.; Di Lisi, S.; Leone, G. Building Information Modelling and Energy Simulation for Architecture Design. *Appl. Sci.* **2021**, *11*, 2252. [CrossRef]
65. Autodesk.Com. Available online: https://www.autodesk.com/ (accessed on 29 April 2024).
66. Wood, H.; Piroozfar, P.; Farr, E. Understanding Complexity in the AEC Industry. In Proceedings of the 29th Annual Conference of the Association of Researchers in Construction Management (ARCOM), Reading, UK, 2–4 September 2013.
67. Paweł, W.; Dzierżak, M.; Kochan, A. Oprogramowanie BIM w projektowaniu systemów sterowania ruchem kolejowym–analiza porównawcza. *Zesz. Nauk.-Tech. Stowarzyszenia Inż. Tech. Komun. W Krakowie Ser. Mater. Konf.* **2020**, *121*, 91–103.
68. Zawada, K. Praca dyplomowa magisterska, Informatyzacja Branż AEC Przy Zastosowaniu Metodologii BIM, w Oparciu o ISO 19650 z Uwzględnieniem VR, AR, VDC Oraz Środowiska CDE. Master Thesis, Szkoła Główna Gospodarstwa Wiejskiego, Wydział Budownictwa i Inżynierii Środowiska, Warsaw, Poland, 2023.
69. Budimex z Nagrodą Za Powykonawczy Model BIM Dla Lidla. Available online: https://www.pb.pl/budimex-z-nagroda-za-powykonawczy-model-bim-dla-lidla-961389 (accessed on 14 April 2024).
70. STRABAG Rozpoczyna Budowę Walcowni Dla Cognor SA. Available online: https://www.strabag.pl/databases/internet/_public/content.nsf/web/PL-STRABAG.PL-PRASA-2023-STRABAG%20rozpoczyna%20budow%C4%99%20walcowni%20dla%20Cognor%20SA (accessed on 14 April 2024).
71. PORR Wykonawcą Biurowca PSE. Available online: https://porr.pl/pl/media/informacje-prasowe/przeglad/informacja-prasowa/news/porr-wykonawca-biurowca-pse/ (accessed on 14 April 2024).
72. Khan, A.; Sepasgozar, S.; Liu, T.; Yu, R. Integration of BIM and Immersive Technologies for AEC: A Scientometric-SWOT Analysis and Critical Content Review. *Buildings* **2021**, *11*, 126. [CrossRef]
73. Tan, S.; Gumusburun Ayalp, G.; Tel, M.Z.; Serter, M.; Metinal, Y.B. Modeling the Critical Success Factors for BIM Implementation in Developing Countries: Sampling the Turkish AEC Industry. *Sustainability* **2022**, *14*, 9537. [CrossRef]
74. Malla, V.; Tummalapudi, M.; Delhi, V.S.K. Perceptions of Built-Environment Professionals on Using ISO 19650 Standards for Information Management. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2024**, *16*, 04523045. [CrossRef]