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The Status of Building Information Modeling Adoption in Slovakia

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Abstract: Building information modeling (BIM) is a key approach for the digitization of the sector. Therefore, states worldwide put BIM at the center of their construction digitalization strategies. However, strategies vary significantly, and so does BIM implementation and its adoption over time, thus making the comparison between countries considerably challenging. Therefore, the first part of this article provides a comprehensive review of available publications in the field of BIM adoption at the national and international level. BIM adoption in Slovakia is systematically analyzed based on an anonymous online BIM survey that focuses on various areas of BIM. The focus of the BIM survey was on the assessment of the readiness of experts who work with BIM methodology, their maturity, skillsets, and BIM adoption motivation, along with the means of communication and collaboration using Common Data Environment (CDE). Furthermore, we focused on the project management perspective, which covers the existence and compliance with BIM execution plan (BEP) evaluation. In the concluding part, requirements, barriers, and future developments are discussed in detail. The BIM survey provides an insight in the current state of the art of BIM in the industry that allows for a better understanding of its potential and a more informed development and implementation of BIM strategies. This study is an important contribution to BIM and digitalization benchmarking that provides valuable information to digitalization policy makers at the governmental and business levels.

Keywords: BIM; BIM adoption; digitization; construction; BIM roadmap; survey

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1. Introduction

Building information modeling (BIM) adoption at a national level is a very long and complex process. But it is an opportunity for the whole construction sector to achieve higher efficiency by adapting to the technologies of the 21st century. "The investment in improving the construction process at public level, represented by BIM methodology, is fundamental in helping ensure the success of digitalization in the construction sector." [1]. BIM is not only a key approach for the digitization of the construction industry, but also a cornerstone for increasingly energy-efficient construction and renovation, contributing to the sector's sustainability. It is necessary to stimulate the market to create a demand for digital skills and appropriately associate them with quality and added value in construction projects. "Governments and public procurers across Europe and around the world are recognising the value of BIM as a strategic enabler for cost, quality, and policy goals." [1]. It is expected that the induced need for digital skills will also contribute to the achievement of the goals set by the European Union (EU), to which Slovakia also committed. However, the use of digital tools such as BIM is still not widespread enough in practice.

Since the introduction of the EU Public Procurement Directive No. 24/2014, the EU encourages public entities to use BIM [2], and it is anticipated that a "full-scale digitalization will lead to annual global cost savings of 13% to 21% in the design, engineering and construction phases and 10% to 17% in the operations phase" [3] and that the "wider adoption of BIM will unlock 15–25% savings to the global infrastructure market by 2025" [4]. The construction industry is, from the perspective of the EU, a rather important sector "responsible for almost 9% of the EU GDP, 7% of employment, and it is composed by 3.1 million businesses." [5].

The broader adoption of BIM in the United Kingdom gained significant momentum with the introduction of the BIM implementation policy and the mandate, beginning in 2016, which required the use of BIM for public projects exceeding GBP 5 million [6]. The goal of the government's strategy was to achieve higher efficiency in the field of construction, calculated as a 20% saving in procurement costs. The introduction of the requirement for public procurement in the UK has clearly increased the number of professionals using BIM. When the strategy was introduced, in 2011, only 13% said that they had adopted it, compared to 2016 when the percentage of those using BIM increased to 54% [6].

The number of projects that are executed using BIM in Slovakia is gradually increasing, and to set appropriate measures within the strategy, it is important to understand a growing need to address specific tasks that result from a collaborative approach, and also what barriers are perceived by the project stakeholders to better aim for their possible elimination [7,8]. Another important part of such a strategy shall aim to the standardization of data exchange and interoperability [9]. Effective interoperability requires not only a set of standards, but also proper implementation. Of course, interoperability can be achieved without standardization, but only if we can accept that each project will be governed by its own rules. Although, in today's era, when high emphasis is placed on efficiency and the correct handling of data in the construction life cycle, such a situation is unacceptable [10–12].

Even though BIM is being discussed at many events and papers, an official document that provides an overview and evaluates the level of its adoption in Slovakia is still missing. It is necessary to know the state of penetration of such technologies in the construction industry, to measure the progress which allows to evaluate the efficiency of the implemented processes and contribute especially to the preparation of a national strategy for BIM adoption. As of now, a national strategy for Slovakia has not yet been formulated or introduced. We believe that our research has the potential to make a substantial contribution to the development of a roadmap, offering valuable insights for the gradual implementation and development process over time.

Specific national statistics on BIM adoption serve as a valuable resource for practitioners in other countries by offering benchmarking and comparison with insights, inspiration, the overview of risks and benefits, and market opportunities. The results also provide a blueprint for the roadmap for advancing BIM implementation in other regions. Having said that, the present study fosters cross-border collaboration and helps create a more standardized and globally competitive construction and design industry. In addition, national statistics can reveal the impact of government policies and regulations on BIM adoption. Other countries can use this information to inform the development of their own policies and regulations related to BIM. The present approach is grounded in a highly representative sample of practitioners, particularly when viewed in relative terms compared to similar surveys conducted in countries with significantly larger populations.

2. Literature Review

Over the past decade, there is an increasing number of papers and publications in publicly available databases that deal with the level of implementation/adoption of BIM at the corporate, regional, national, or even international level. Several aspects of cooperation and a collaborative approach are being evaluated, the status of implementation within a particular period is measured and compared, and the impact of the BIM methodology on the construction industry is analyzed. The problem, however, remains that the scope and structure of the questions are non-uniform, as alongside the variety of evaluation scales.

There is a lack of a uniformity in the approach of assessing the adoption of BIM in countries in a systematic manner. In contrast to the diversity of approaches to BIM adoption research, there is the BIMe initiative, in which the authors focus on a uniform methodology for data collection and evaluation, published in two complementary papers [13,14], combining conceptual structures with data collected from experts across a number of countries. The first paper, "Macro-BIM adoption: conceptual structures", delimits the terms used, reviews applicable diffusion models, and clarifies the research methodology. The second paper, "Macro-BIM adoption: comparative market analysis", employs these concepts and tools to evaluate BIM adoption and analyze BIM diffusion policies across several countries. This methodology was used by several countries that followed up on the methodology, collected their own data, and subsequently published a report as part of the BIMe initiative. The countries that joined the initiative are Canada, Brazil, Hong Kong, Ireland, Peru, Spain, and Russia [15]. It is expected that other countries will join the initiative, which will enrich the database of information and enable a better comparison of the situation in the given countries.

Besides [14,15], another paper aimed to develop and validate a Unified BIM Adoption Taxonomy (UBAT) [16], and to identify driver clusters and their factors that have influence on the first three stages of the BIM adoption process, namely, the awareness, interest, and decision stages. The researchers also focus on the comparation of their effects on each of the stages. As the authors state, this publication contributes to the understanding of the BIM adoption process and the constructs that influence its stages, and provides insights into the explanation of terms Adoption, Implementation, and Diffusion that are commonly used as synonyms.

Some authors present a uniform approach to the evaluation of BIM from the perspective of implementation strategy [17–21], while others focus on the development of the mechanisms for the assessment of BIM maturity [22].

As mentioned above, most of the authors focused only to limited regions. There are several publications available in the category of national implementation evaluation surveys. For a better understanding and visualization of the extent of this research, publications per country that are included in this paper are presented in Figure 1. Countries marked blue form part of this research, while countries marked grey are not included.

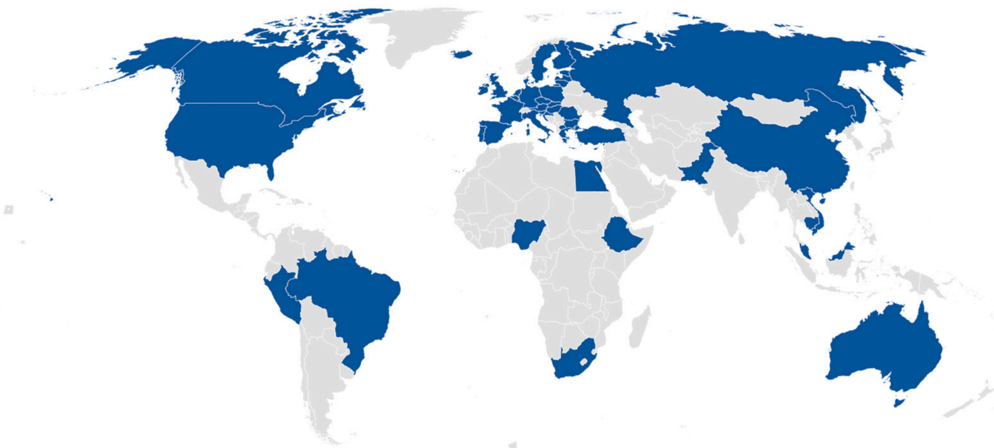

Figure 1. Overview of countries included in the literature review.

In total, BIM adoption status was found in 51 countries starting from 2007 (US). The data distribution per year of publication are presented in Table 1. The first row represents the count of papers found in the open access research databases where each country is represented by one paper; in the case of more papers available, this is the first one that was published. It is important to note that at the time of preparation of this survey (2016), only five countries could be found with reliable papers describing the actual status of the implementation of BIM.

Table 1. The overall number of publications distributed over time of publication.

	2007	2011	2016	2017	2019	2020	2021	2022	2023
Count	1	2	2	2	33	2	3	5	1
Ratio	2.0%	3.9%	3.9%	3.9%	64.7%	3.9%	5.9%	9.8%	2.0%

Two key periodical reports have been identified; the first is the "SmartMarket Report" [23], prepared by Dodge Data & Analytics, formerly known as McGraw-Hill Construction, providing information about the status of BIM adoption in the United States since 2007. The other is the "National BIM Report" by National Building Specification, United Kingdom [6], collecting and providing information since 2011.

It is rather interesting that one of the first nations to adopt BIM was Norway [24]. Norway already has requirements and standards for the public sector. BIM has been used by The Statsbygg since 2007, and it was made mandatory for all projects in 2009, but the status of overall BIM implementation at country level cannot be found. Another study indicates the early adoption of BIM in Nordic countries. Findings from a survey taken in Iceland [25] indicate that BIM was being used by almost 40% of respondents, largely architects and engineers, back in 2011.

Besides US and UK, which provide long-term data on the level of adoption, there is a growing number of publications evaluating the state of the art in individual countries such as Italy [26], North Macedonia [27], Iceland [25], Egypt [28], South Africa [29], Malaysia [30], China [31,32], Peru [33,34], Brazil [35], Vietnam [36], Pakistan [37,38], Nigeria [39], Turkey [40], Ethiopia [41], Ireland [42], Cambodia [43], Australia [44], and New Zealand [45]. Data evaluation in all these countries is executed without a future repetition of data collection and therefore represents limited information about the state of the issue in a given year and selected marginal conditions. In the countries where the survey focused on individual aspects of BIM adoption was conducted, the focus varied and, as mentioned, the methodology is not uniform.

In the Asian region, one study [31] examines the challenges to BIM adoption faced specifically in the Chinese construction industry across architecture, engineering, and construction, and how current Chinese BIM adoption in practice differs from overseas BIM adoption strategies. In this region, another study [32] quantitatively explores the macro characteristics and dynamics of BIM adoption. The results indicate that BIM adoption in China presents significant regional imbalances and scale-free network features, with low connectivity as a whole and a significant island effect locally. Researchers in Vietnam [36] used a hybrid research approach of surveys and expert judgment, to discuss the most popular barriers in BIM adoption in the construction industry in Vietnam along with strategies to grow the industry's BIM capacity, focusing on the system of relevant laws and regulations to govern the BIM-enabled construction projects, and highlighting the need for a new set of standards and codes for BIM-related processes.

Researchers in Spain [46] followed up on the mentioned BIMe initiative as part of their research and used the methodology to evaluate the state of BIM implementation in the country. The entire Spanish construction sector was evaluated. Such an output is very valuable from the point of view of further use, as this approach makes it possible to compare data between countries, even if such evaluations are not yet published.

In Latin America, two countries have published BIM adoption data from selected parts of the industry. One study [33] was carried out in Peru, focusing on contractors. Two cross-sectional data sets were collected with a limited number of respondents to evaluate changes in a modified technology adoption model regarding BIM adoption. Another study [34] investigated the systemic adoption of digital innovations in construction, and was aimed at formulating a model of systemic BIM adoption. Another Latin American paper [35] investigated the main barriers faced by a large Brazilian construction company in their efforts to thoroughly implement BIM. The findings showed that BIM has improved the information management of the design itself and its interface with the construction phase.

In addition to [23], a survey [47] was executed as a solid base for the BIM transition process in Canada and aimed to present a detailed view of the role that BIM plays in the future of the industry, with a special attention to the perceived benefits and barriers to BIM implementation. It was found that resistance to change is the number one barrier, followed by the lack of knowledge/skills and the lack of training [48]. Another research paper identified the gaps in terms of macro-BIM adoption in order to develop a comprehensive strategy for BIM deployment in the Quebec region [49].

A separate category is research that includes several countries, but a very limited number of these papers are available. Oned paper [50] evaluated a wider range of countries and aimed at assessing the gaps in BIM adoption among the 28 EU countries and the barriers related to its implementation, which also includes Slovakia, but it is based on only four respondents. Slovakia is also partially described in [51,52].

Another study [53] tends to describe worldwide status at the intercontinental level, including data from 44 countries and 7 continents, although providing very limited informative value due to the small number of respondents (168 in total) and very limited evaluation.

Research Gaps

Over time, a growing number of articles providing information based on evaluation of the current state of BIM, mostly focus on a specific country. As can be seen from the literature survey, most publications in this area are from 2019, with up to 64.7% of the publications that are included in the research within this article. Although BIM adoption surveys have contributed significantly to research, there are still several research gaps and areas where further investigation could provide valuable insights. The key factor in evaluating the status are the data, especially in relation to the number of respondents, which makes it possible to determine a more accurate rate of BIM adoption and a lower margin of error. In this research study, we therefore aim to provide a solid number of respondents, guaranteeing higher level of confidence.

After the review of the available literature, the following potential research gaps were identified in the field of BIM adoption surveys:

1. Long-Term Impact and Sustainability—Many BIM adoption surveys focus on short- to medium-term impacts. Research that explores the long-term impacts of BIM adoption on project outcomes, maintenance, facility management, and the entire lifecycle of built assets could provide a more comprehensive understanding. We aim therefore to collect data on an annual basis.
2. Smaller Projects and Firms—While many surveys target larger projects and organizations, there is a lack of research on BIM adoption in smaller projects and firms. Investigating the challenges, benefits, and strategies specific to these contexts could fill this gap.
3. Cultural and Organizational Factors—Cultural and organizational factors can significantly influence BIM adoption. Research that delves deeper into how different cultural contexts and organizational structures impact the adoption process could provide valuable insights.
4. Legal and Contractual Challenges—Investigating the legal and contractual challenges arising from BIM adoption, such as liability issues, intellectual property rights, and standard contract clauses, could be beneficial.
5. Comparative Studies across Countries—While some studies focus on BIM adoption within a specific country, more cross-country comparative studies could reveal differences and similarities in adoption rates, drivers, and challenges.
6. Governance and Policy—Research on the role of government policies, regulations, and industry standards in driving or hindering BIM adoption could shed light on the broader ecosystem within which adoption takes place.

3. Methodology

3.1. Research Question

The following two research questions have been addressed:

1. *To what extent has BIM been adopted across different construction projects and organizations in Slovakia's built environment industry?*
2. *Which factors influence the level of BIM implementation in Slovakia's built environment industry?*

This research question serves as a solid foundation for conducting a comprehensive study on BIM adoption in Slovakia, considering both the extent of adoption and the factors that contribute to or hinder its implementation within the country's built environment industry.

This research could lead to valuable insights for understanding the current state of BIM usage in Slovakia and identifying key drivers and barriers in the adoption process. It offers a holistic approach to understanding the influence of BIM on project outcomes, stakeholder interactions, and the optimization of processes. The research questions also suggest an exploration of both quantitative and qualitative data to gain a comprehensive understanding of the implications of BIM adoption.

3.2. Research Goals and Objectives

The main goal of this research is to obtain an accurate assessment of the actual BIM adoption in the Slovakian construction industry and to thoroughly understand the underlying factors affecting the adoption and implementation of BIM in Slovakia's construction industry. To achieve these goals, we iteratively designed and conducted a comprehensive survey, which served to address specific research objectives.

The specific objective that we targeted with an online anonymous BIM survey in the context of BIM adoption evaluation was to gather measurable quantitative and qualitative insights, feedback, and specific data from individuals directly involved in or impacted by the BIM implementation process. The detailed BIM survey-induced objectives are as follows:

1st objective: To assess the extent of BIM adoption

This objective focuses on quantifying the level of BIM adoption across diverse construction projects and organizations in Slovakia's built environment industry. It involves collecting data to determine the prevalence of BIM usage, such as the percentage of projects using BIM, the types of projects, and the proportion of organizations that have integrated BIM into their processes.

2nd objective: To identify key implementation challenges

By asking respondents about the challenges they have encountered during the BIM implementation process, or the barriers that stopped them from adopting BIM, the survey can help identify specific pain points, obstacles, or issues that need to be addressed. This information can guide improvement efforts and resource allocation.

3rd objective: To examine industry-specific trends and practices

This objective involves investigating how BIM is being used within specific sectors of Slovakia's built environment industry, such as architecture, engineering, construction, and facility management. By examining industry-specific trends and practices, the study can provide insights into tailored strategies and applications of BIM.

4th objective: To conduct a comprehensive comparative analysis between the state of BIM adoption in Slovakia and international best practices.

This objective seeks to draw parallels and distinctions, and plays a pivotal role in standardizing the methodology for subsequent comparative analyses of other countries. As of the time of writing, the research team is actively collecting data from other countries to support this ongoing effort.

3.3. Paper Structure and Organization

The paper structure and organization of this research, after a general overview of the approach, is as follows. First, the materials and methods are explained. The preparation of the survey is described in Section 3.5. The details of the distribution strategy are presented in Section 3.6.

The results of the research are divided into three subsections. Section 4.1. is focusing on information about the respondents, Section 4.2 focuses on the use of BIM, and Section 4.3 is the final part of the survey contributing to the identification of barriers, assessing the need for BIM, and estimating its future development at the company level. The key findings are discussed within Section 4 and its subsections.

Finally, theoretical contributions are presented in Section 5 and the conclusion of this paper in Section 6.

3.4. Materials and Methods

As an initial step, we conducted a systematic review of available publications (Section 2), which were centered on evaluating the state of BIM adoption in individual countries. We examined survey questions from other sources identified in our review and selected the most pertinent ones for gauging BIM adoption in Slovakia.

Next, our approach was established including the form of distribution. In order to capture a relevant number of respondents, the following boundary conditions were set for conducting the survey. The survey had to meet the following criteria:

- Simple yet explicit questions;
- Flexible set of questions using logic;
- Short overall duration;
- Anonymous data collection;
- On-line format.

Formulating short and concise questions allows a higher engagement of the prospective respondents, allowing them to answer in a shorter time, which will increase the number of submitted questionnaires as a result. The prospective duration of the survey was set to 5 min maximum. According to this criterion, the content was adapted to fit within the desired timeframe. The strategy also emphasizes communication with potential respondents, assuring them that the survey will not be time-consuming. Through the use of response-based logic jumps, we facilitated survey personalization based on the feedback provided and ensured that irrelevant questions were automatically skipped. Incorporating logic in the questionnaire makes the questions more targeted and contributes to a higher rate of completion. Logic function is the ability to respond to the participant´s answers and reduce the number of skipped questions, due to their irrelevance.

The survey was carried out in the form of an anonymous online questionnaire, and the target group covered all stakeholders of the construction industry in a whole project lifecycle.

3.5. Preparation of the Survey Structure

The questionnaire consists of 15 questions, and it is divided into three parts (see Figure 2). The first part contains 5 questions related to information about the respondent. The first question provides information about the geographical location of the respondents within the country. The survey distinguishes respondents further according to type of construction, field of occupation, and profession. The last question segregates respondents based on the size of the companies by which they are employed.

From a geographical point of view, Slovakia is divided into 8 parts—regions. This question makes it possible to compare the state of individual regions and the level of BIM adaptation on the basis of territorial affiliation.

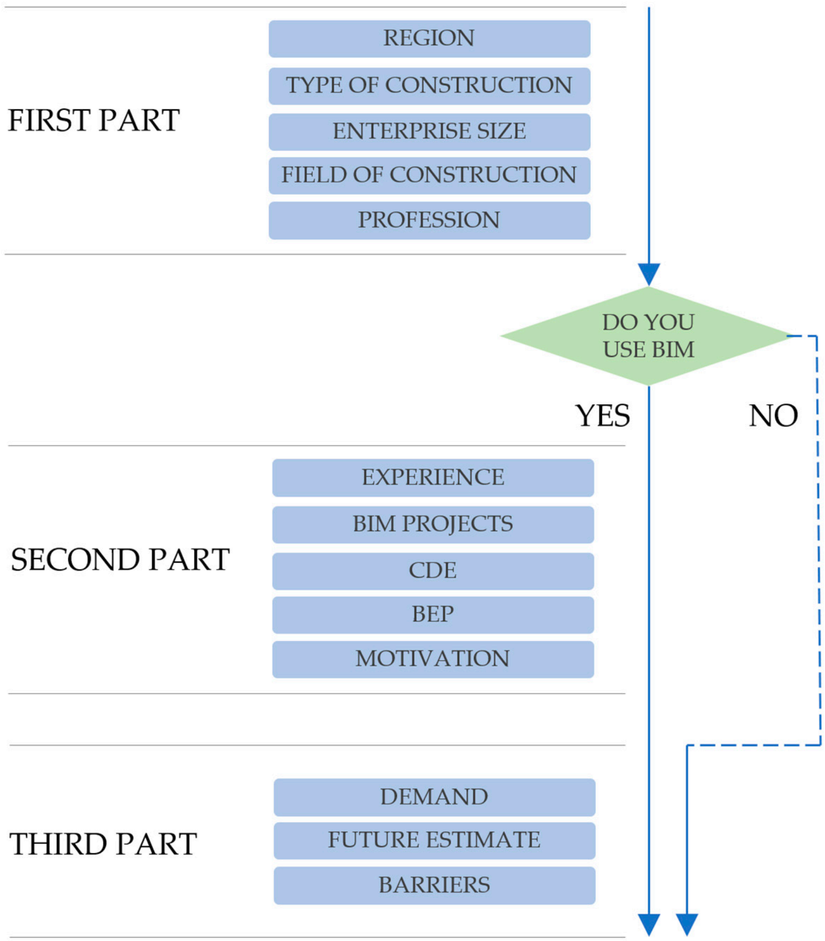

Figure 2. Survey logic overview.

When working in the field of BIM, it is important to divide projects into two fields, civil engineering (buildings) and infrastructure, as they usually have different levels of BIM usage. The division based on field and profession enables various comparisons, for example, the use of BIM in different phases of the construction life cycle.

The size of companies was adapted to Slovak specifics, but is in alignment with the Organisation for Economic Co-operation and Development (OECD) [54] definition of enterprises by business size. Small and medium-sized enterprises (SMEs) are subdivided into micro enterprises (fewer than 10 employees), small enterprises (10 to 49 employees), and medium-sized enterprises (50 to 249 employees). A large enterprise is defined as one that employs 250 or more people. This allows us to be more specific and dive deeper into an understanding of differences between enterprise structures.

The second part is the main part of the survey, and it focuses on the level of BIM usage and adoption. Question 6 divides the set of questions intended only for respondents who already use BIM. Questions 7–12 are aimed at the overall level of BIM use on projects, and capture information about experience, the percentage of BIM deployment in the respondent's company between individual projects, the use of CDE, etc. For respondents who do not use BIM, questions 7–12 are irrelevant, and respondents are redirected to question 13.

The third set of questions, questions 13–15, is common to all respondents. It focuses on barriers to the use of BIM, evaluates the demand for BIM in the local market, and provides an estimate of future use.

3.6. Survey Distribution Strategy and Data Collection

Selecting appropriate distribution channels is always challenging. Aiming at and targeting the right audience is crucial, especially when a certain level of expertise is expected or when the target group is specific, having in mind that we shall keep focusing on the value of energy skills. This approach differs significantly from those that are aiming at a general audience. In order to ensure broad data collection, appropriate distribution channels for survey dissemination were selected. Public professional portals in architecture, engineering, and construction, including facility management (AEC), and internal databases of professional and professional associations were chosen as distribution channels for survey dissemination. As part of the strategy, two branches of questionnaire distribution were recognized. The first branch aimed at public channels via professional portals and journals, also including social media in the AEC industry. The second branch aimed at distribution through professional associations, chambers, and cooperating organizations. The Typeform platform was used as a data collection tool.

4. Results and Discussion

The survey is a follow-up to the original research from 2017. In 2017–2019, a survey of 15 questions was carried out. In 2020, four questions were modified regarding project management, compliance with BEP, and the use of CDE. Due to actual market developments, the profession BIM manager/BIM coordinator [52,55–57] was included. The evaluation of the survey is mostly based on 2022, but provides an overview and deep insights based on previous years of the survey.

In 2022, 1058 respondents participated in the survey. The total number of respondents for 2017–2022 was 10,323. The first row of Table 2 contains the number of respondents in a given year. The second row shows the percentage of the total number of respondents for the monitored period of six years. It is possible to assume that the modified content of questions, introduced in 2020, could have led to a decreased number of respondents. During the period 2017–2019, the average time to complete the questionnaire was 02:58, and in 2020–2022, it increased by almost 20 s to 03:16.

Table 2. The overall number of respondents and the margin of error per year.

Year	Confidence Level	2017	2018	2019	2020	2021	2022
No. of respondents		2327	1753	2087	1727	1371	1058
Ratio		22.54%	16.98%	20.22%	16.73%	13.28%	10.25%
Margin of error	95%	2%	2%	2%	2%	3%	3%
Margin of error	99%	3%	3%	3%	3%	3%	4%

The third and fourth row of Table 2 represent the calculated margin of error for the 95% and 99% confidence levels, respectively. The 95% confidence level is most common [58,59] and represents the probability with which the estimation of the location of a statistical parameter in a sample survey is also true for the population [60]. The statistical sample refers to the total number of workers in the construction industry, which in the given period is set at 160,000, based on data from the Statistical Office of the Slovak Republic.

The margin of error (confidence interval) describes how much the survey results reflect the views of the overall population. The larger the margin of error, the less confidence exists that the results represent the entire population.

$$\mathrm{MOE}_{\gamma} = z_{\gamma} \times \sqrt{\frac{\sigma^2}{n}} \quad (1)$$

Equation (1) Margin of error, Description: MOE—Margin of Error, n—Sample size, σ—Population standard deviation, z—Z-score [58].

Based on a margin of error calculated for selected confidence levels (for the 95% confidence level, MOE equals 2%, resp. 3%, and for the 99% confidence level, MOE equals 3%, resp. 4%), we can conclude that the statistical pattern of respondents in terms of number shows very high accuracy values, and the chances are very high that the arithmetic mean of the population is exactly within the margins of error which were established for the survey based on a sample.

4.1. First Part of the Survey

As mentioned, from a geographical point of view, Slovakia is divided into 8 regions. This question allows to compare the status of individual regions and shows the penetration of interest in BIM at the level of particular regions; it is primarily useful for the local market and studies, whereas for international application this part may be irrelevant.

The largest number of respondents are located in the region of Bratislava, 37.52%. Other regions are listed according to the proportion of representation in the survey—Žilina 12.29%, Košice 11.25%, Prešovský 9.83%, Banská Bystrica 8.51%, Trenčín 7.56%, Nitra 7.28%, and Trnava 5.77%.

The regional representation of the participants in the survey is presented on the map of the territorial (regional) division of Slovakia, shown in Figure 3. The intensity of the blue color is used to express the proportion of representation and is supplemented with the corresponding value. The more respondents, the more intense the color used.

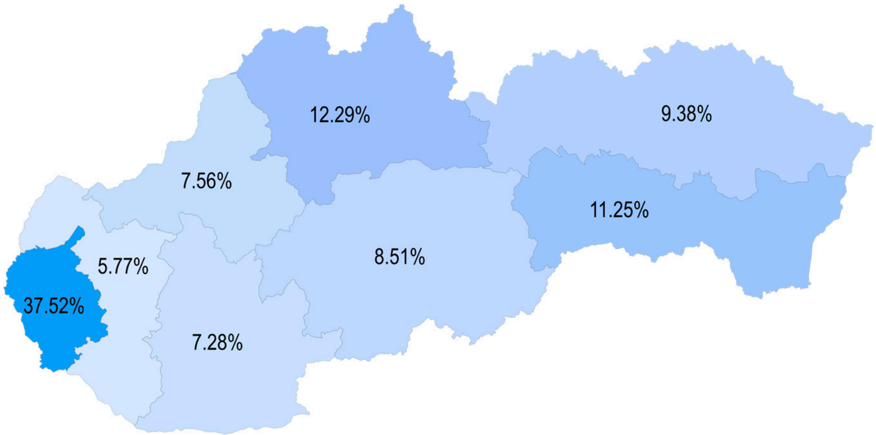

Figure 3. Slovak regions by the proportion of their respondents in the survey.

During the implementation phase, it is important to know the structure of business enterprises that operate on the market. It has an impact on the way BIM is integrated to the company processes and the pace at which the progress of use can be assumed in the near future. As part of the survey, the question regarding the size of business enterprises was adapted to Slovak specifics but respects the definition of enterprises in terms of size according to the OECD. The survey provides more detailed categories.

Micro enterprises have the largest representation in the survey (50.00%), covering two categories in the survey, followed by small enterprises (17.30%) and medium-sized enterprises (17.11%), while large enterprises have the lowest representation ratio (15.60%). Detailed information is presented in Table 3.

When executing projects using BIM, it is important to distinguish between projects focusing on buildings and infrastructure projects, which usually have a different approach from the perspective of a process of BIM delivery, and a rather different level of actual implementation. Most of respondents were working with buildings (64.65%), while a little over one-third were working on infrastructural projects (35.35%) (see Table 4).

Table 3. Statistics of the companies represented in the survey.

Overview	Survey Category	OECD Category	No. of Participants	Percentage of Participants
Estate Business Size based on No. of Employees	1–4	Micro Enterprise	430	40.64%
	5–10	Micro Enterprise	99	9.36%
	11–20	Small Enterprise	76	7.18%
	21–49	Small Enterprise	107	10.11%
	50–99	Medium-sized Enterprise	78	7.37%
	100–249	Medium-sized Enterprise	103	9.74%
	over 249	Large Enterprise	165	15.60%
Civil Engineering (Buildings)			684	64.65%
Infrastructure (Other construction)			374	35.35%

Table 4. Overview of the occupation fields and professions of participants represented in the survey.

Overview of the Occupation Field and Profession		No. of Participants	Percentage of Participants
Occupation field	Architecture and Engineering	515	48.68%
	Construction	284	26.84%
	Surveying	120	11.34%
	Development	63	5.95%
	Other	76	7.18%
Profession	Architect, Engineer	322	30.43%
	Site manager, Project manager	266	25.14%
	Engineer (HVAC, MEP)	140	13.23%
	Structural engineer	81	7.66%
	Surveyor	64	6.05%
	Higher manager, CEO	58	5.48%
	BIM manager, BIM coordinator	37	3.50%
	Other	90	8.51%

Table 4 shows the areas of activity and the breakdown of respondents in terms of professions. Only the areas and professions with the largest representation were selected for publication. The rest were merged into one category—Other. The highest representation in the survey is that of a group of respondents working in the field of designing buildings, architecture and engineering (48.68%), followed by representatives from the field of construction (26.84%), surveyors (11.34%), and development (5.95%), while other areas, such as facility management, public institutions, education, business, and others, were grouped into the Other category, with a representation of 7.18%.

The most represented professions are architects, engineers (30.43%), construction managers, project managers (25.14%), and engineers—professions including heating, ventilation, and air conditioning (HVAC), mechanical, electrical, and plumbing (MEP), etc. (13.23%). The new profession BIM manager or BIM coordinator is represented at a rate of 3.50%. An overview of professions is included in Table 4.

From the first part of the survey, we can summarize that the typical respondent is an architect/engineer from a micro-enterprise in Bratislava who designs buildings.

4.2. Second Part of the Survey

The second part of the questionnaire is the main part which focuses on the level of BIM usage and assesses individual characteristic aspects of BIM collaboration and cooperation. Based on a negative answer to question 6, "Do you use BIM?", respondents who do not actively use BIM are redirected to question 13. Questions 7–12 are irrelevant for them, and therefore it is neither necessary nor appropriate to answer them. It is assumed that doing so would negatively affect the number of completed questionnaires, resulting in a lower number of responses, or it could cause a lower credibility of the evaluation, as it is assumed that the respondent would not be able to answer appropriately.

Respondents who already use BIM proceed to questions 7–12. These are aimed at the overall rate of BIM use on projects, and capture information about user experience, the percentage of BIM deployment on projects in their company, compliance with BEP, the use of CDE, etc.

In 2022, the rate of BIM adoption in Slovakia reached 21.08% (see Figure 4) and thus had slightly increased by 4% in the previous 6 years.

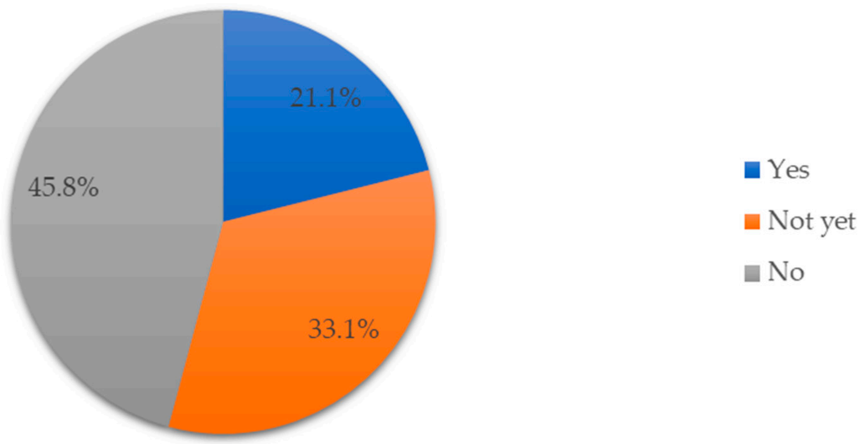

Figure 4. Overall use of BIM in Slovakia, 2022; the blue color represents those respondents who already use BIM, the orange color represents those who do not yet use BIM, but are interested in the methodology, and the grey color represents those who neither use BIM nor are interested in it.

The moderate and gradual increase is mainly due to the absence of a national BIM implementation strategy. Therefore, there is no prospective requirement for the mandatory use of BIM in public projects. Countries (e.g., US, UK, CZ, DE, etc.) that introduced the obligation to use BIM in public projects typically observe a higher increase within the 5-year implementation phase. Naturally, we can observe a decreasing number of respondents who do not use BIM (45.84%).

An overview of the results of the overall use of BIM during the period 2017–2022 is presented in a form of a bar chart—Figure 5.

When comparing the areas of civil engineering (27.78%) and infrastructure (8.82%), we can conclude that BIM has penetrated mainly into the areas of building design. The difference in use is almost 20%. While the buildings sector (27.78%) is almost 7% above average (21.08%), infrastructure is less developed at a level of approx. 12% lower than the national average. The details are presented in Table 5.

Looking at the year-to-year development (Figure 5), a slight increase in the adaptation of BIM can be observed, not only at the national level (increase by 4%), but also in the two assessed areas—buildings and infrastructure. In the area of buildings, the change within the monitored period represents an increase of 5.8%. In the area of infrastructure, the increase is slightly lower (1.5%). The group of professionals on the market who are not yet using BIM, but are interested in the methodology, varies over the years and it is volatile. For those who answered that they do not use BIM, understanding they are not even interested in this topic, a slight decrease from 51% in 2019 to 45.84% in 2022 can be observed. A detailed overview is presented in Table 6.

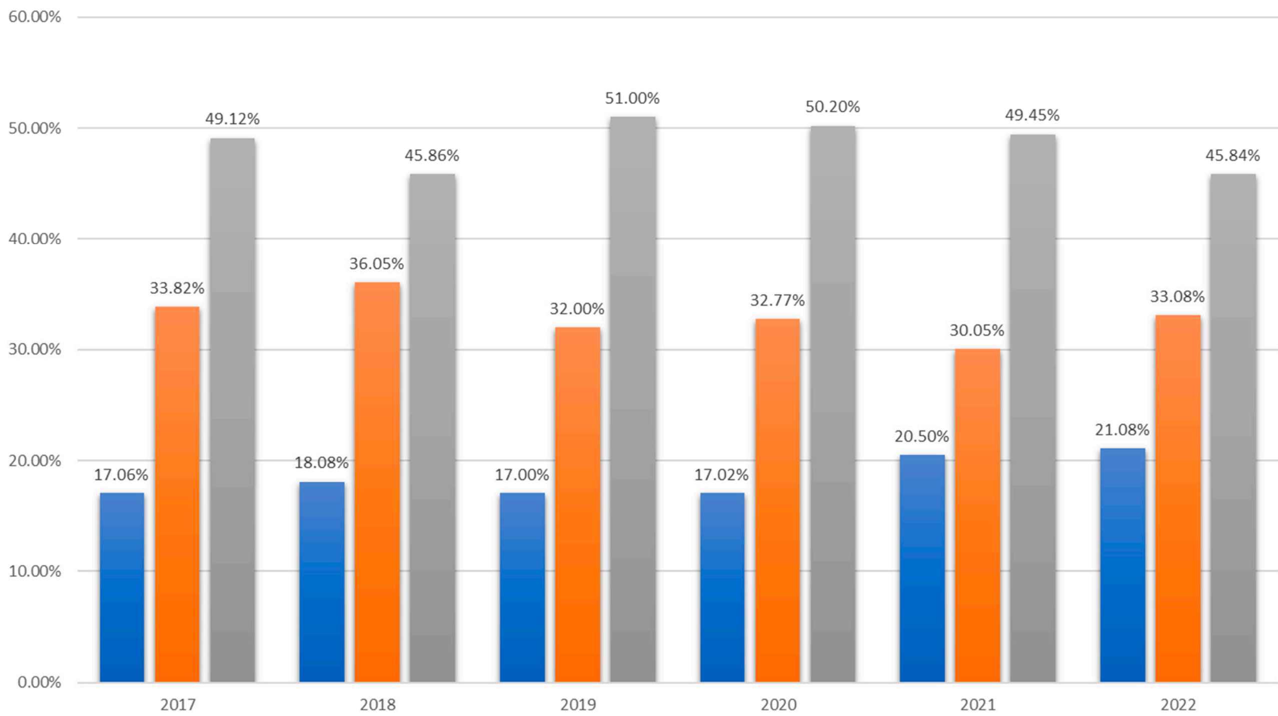

Figure 5. Overview of BIM adoption in Slovakia in the period 2017–2022. Color legend: the blue color represents those respondents who already use BIM, the orange color represents those who do not yet use BIM, but are interested in the methodology, and the grey color represents those who neither use BIM nor are interested in it.

Table 5. Answers to question 6 in 2022.

Do You Use BIM?	No. of Participants		Percentage of Participants
BIM adoption in Slovakia	Yes	223	21.08%
	Not yet	350	33.08%
	No	485	45.84%
Civil Engineering (Buildings)	Yes	190	27.78%
	Not yet	211	30.85%
	No	283	41.37%
Infrastructure (Other Construction)	Yes	33	8.82%
	Not yet	139	37.17%
	No	202	54.01%

By combining the data from the questionnaires, it is also possible to evaluate the level of BIM usage among individual professions. This article presents five professions that had the highest rate of BIM adoption in 2022.

Structural engineers (33.3%) are among the most developed professions together with architects/engineers (28.9%). In these two professions, the adoption rate of BIM is above average. They are followed by engineers of professions such as HVAC and MEP (15.7%), where a drop under the average can be observed. This corresponds to the development in practice. Although the number of professions continues to rise, it is still below average. In addition to the three occupation categories mentioned above, two more (site manager/project manager and land surveyor) are presented in Figure 6, which also includes a yellow line representing the average (in 2022).

Table 6. Overview of answers to question 6 in the period 2017–2022.

Do You Use BIM?		2017	2018	2019	2020	2021	2022
BIM adoption in Slovakia	Yes	17.1%	18.1%	17.0%	17.0%	20.5%	21.1%
	Not yet	33.8%	36.1%	32.0%	32.8%	30.1%	33.1%
	No	49.1%	45.9%	51.0%	50.2%	49.5%	45.8%
Civil Engineering (Buildings)	Yes	22.0%	22.8%	22.6%	23.2%	28.0%	27.8%
	Not yet	34.1%	35.2%	31.5%	31.2%	29.5%	30.8%
	No	43.8%	42.0%	46.0%	45.7%	42.5%	41.4%
Infrastructure (Other Construction)	Yes	7.3%	7.1%	5.6%	5.7%	7.8%	8.8%
	Not yet	33.2%	38.4%	34.1%	35.7%	31.0%	37.2%
	No	59.5%	54.4%	60.3%	58.5%	61.2%	54.0%

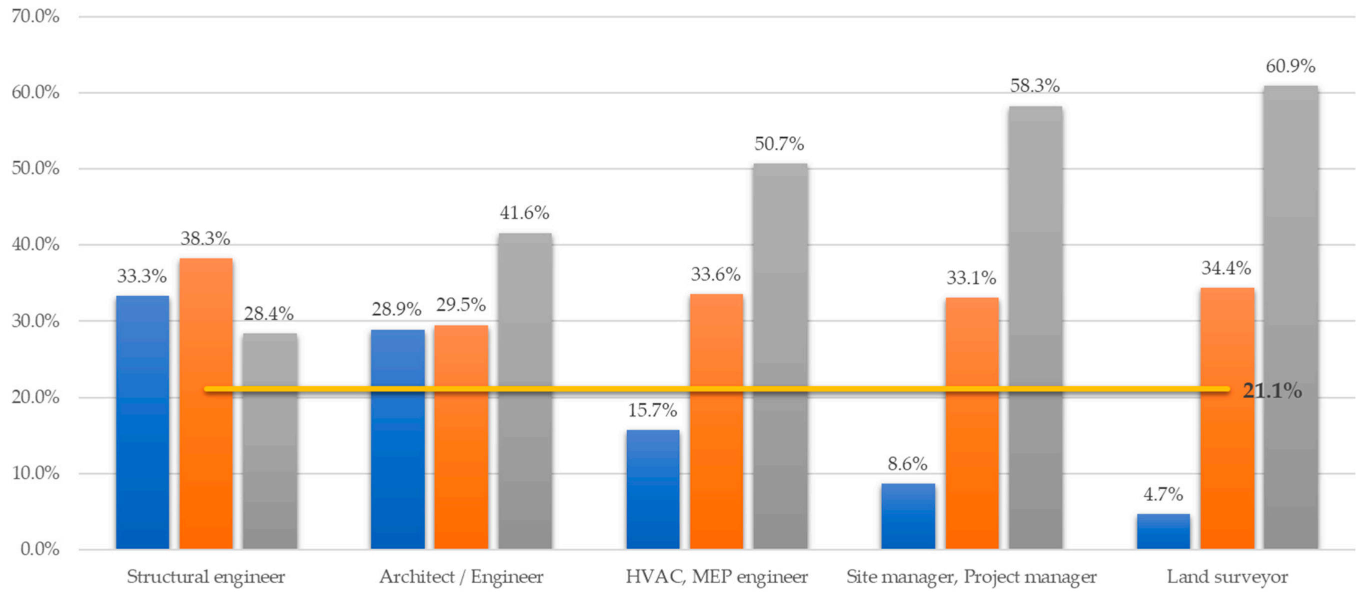

Figure 6. Use of BIM among professions in 2022. Color legend: the blue color represents those respondents who already use BIM, the orange color represents those who do not yet use BIM, but are interested in the methodology, and the grey color represents those who neither use BIM nor are interested in it. The yellow line represents the average of the year 2022.

The number of projects for which a building information model is available increases year by year, and at the same time, the experience of individual participants in the life cycle grows. With the increasing number of projects, the demand for human resources and their skills also logically increases, and new types of positions are created specifically in the field of BIM. Based on this survey, in the Slovak construction market in 2022, there were 3.40% of experts who held the position of BIM manager or BIM coordinator. Figure 7 shows the ratio of represented professions in terms of the area of their occupation. Professions from the field of design are most represented (50.7%), covering positions such as architect, engineer, structural engineer, and HVAC/MEP engineer. More than 33% are professions connected with construction activities, such as construction manager, construction supervisor, project manager, etc.

We can observe that the number of BIM managers and coordinators is gradually growing, from 2.20% (2020) to 2.48% (2021), and finally to 3.40% (2022).

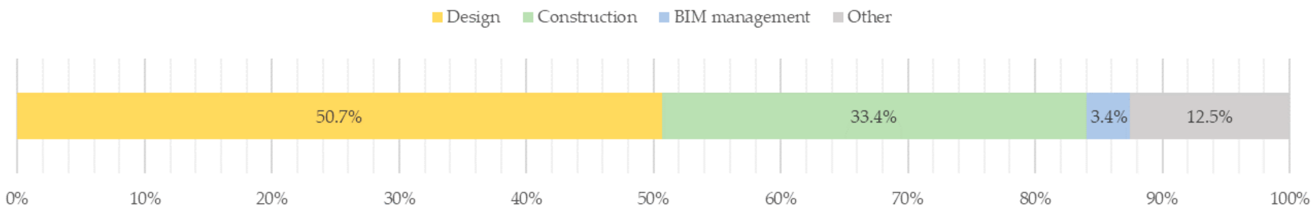

Figure 7. The number of BIM managers and coordinators in the market.

From the point of view of division by area of operation, the majority of BIM managers and coordinators operate in the field of buildings (61.11%). The remaining 38.89% work on infrastructural projects. The ratio is primarily determined by the number of BIM projects that are executed in these areas, where buildings clearly predominate (see Figure 8). The proportion is influenced by the growing number of BIM managers and coordinators who start working on infrastructural projects. The details are presented in Table 7. No data are available for the period 2017–2019, since this category of profession was only included in 2020.

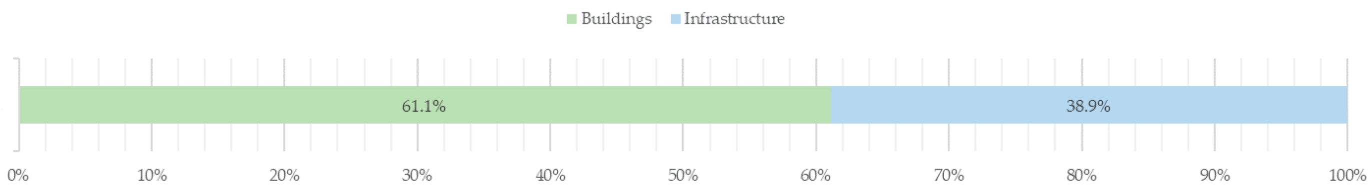

Figure 8. Comparing the ratio of BIM managers and coordinators in the field of buildings and infrastructural projects.

Table 7. Representation of BIM Managers and Coordinators over time.

Share of BIM Managers and Coordinators	2020	2021	2022
Buildings	81.82%	82.3%	61.11%
Infrastructure	18.18%	17.7%	38.89%

Looking at the individual areas of the project cycle, we can conclude that, based on the information from the survey, BIM penetrates the development area the most (41.3%), followed by the design area (29.1%). Both areas are above the average in terms of BIM adoption. A significant decrease in BIM adoption is observed in the field of construction (11.3%), which is 9.8% below the average. Digital tools on-site are in general a global issue in such a conservative field as the construction industry [61,62].

The percentage of BIM coordinators and managers involved in infrastructure projects has shown a more significant increase compared to the proportion of companies utilizing BIM for such projects, as illustrated in Table 7. This disparity can be attributed partly to differences in absolute numbers and partly to variations in the internal organizational structures of companies that predominantly engage in building projects versus those focused on infrastructure projects.

There is great opportunity to use information models that were already prepared during the design phase. The area of facility management is even more noticeable, where, according to the survey, current utilization is 0% (see Figure 9). However, the phase of construction and also operation and maintenance (facility management—FM) are key in terms of applying the benefits of BIM from the perspective of the building life cycle [63–65].

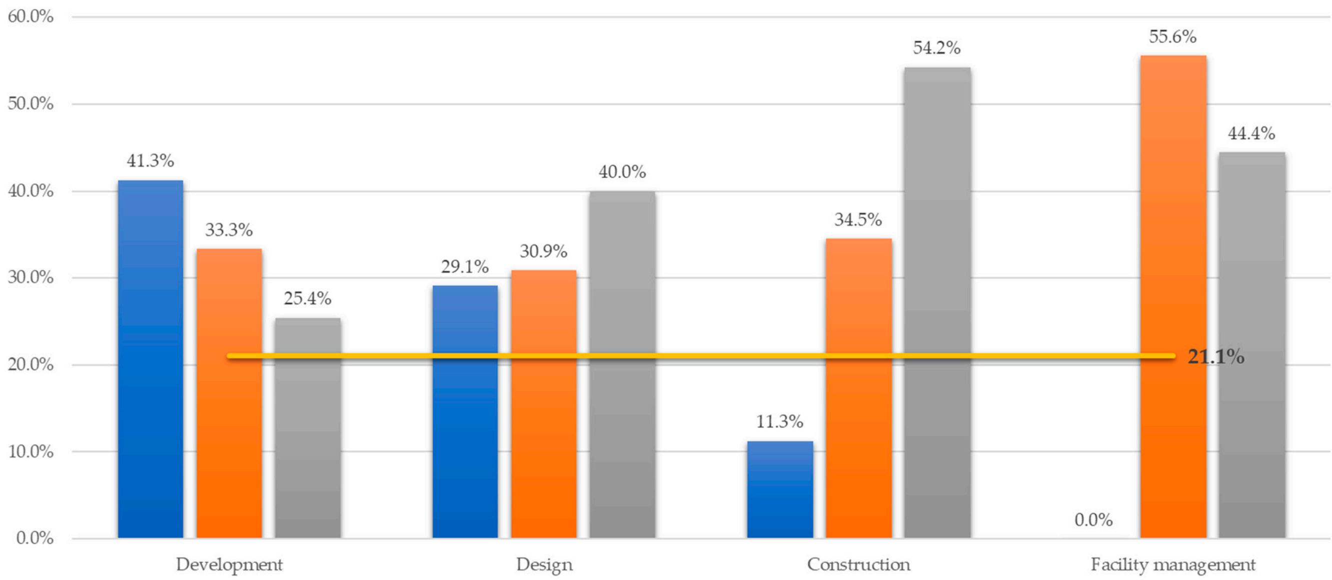

Figure 9. Use of BIM in the project cycle, in 2022. Color legend: the blue color represents those respondents who already use BIM, the orange color represents those who do not yet use BIM, but are interested in the methodology, and the grey color represents those who neither use BIM nor are interested in it. The yellow line represents the average of the year 2022.

It is also important to mention that the use of BIM represents the opportunity for the FM sector to extend services by managing a virtual representation (information model) throughout the entire life of the building, up to its demolition [66]. Today, in the BIM context, the term "digital twin" is quite often inappropriately used as a synonym with the building information model of the operation phase. Based on the available standards, the correct term is the asset information model (AIM). The operational phase is defined by STN EN ISO 19650-1 as the part of the life cycle during which the asset is used, operated, and maintained. The asset is a relatively unused term in the field of construction. It can mean any building or structure, but it is defined as an item, thing, or entity that has potential or actual value for the organization [10].

In the process of preparing and processing the BIM model, BIM-related activities are incorporated into the teams of investors, design offices, and construction companies. These require professional specialization and as they are rather time-consuming, it is no longer viable to assign these activities to employees with other tasks and specialization. This mainly concerns the preparation of EIR and BEP documents, and internal BIM manuals, but also the processes of the control and coordination of BIM models and their further processing, e.g., during quantity take-off, budget creation, and various analyses.

Currently, slightly more than 18% of active BIM users state that they have BEP on all projects. From this point of view, the vast majority of BIM projects (almost 62%) are probably initiated by an internal company request, as BEP is absent on these projects, and we can therefore consider the project as unmanaged (see Table 8).

Table 8. Level of cooperation, management, and collaboration.

BEP/CDE		No. of Participants	Percentage of Participants
Do you follow the BEP on projects?	All projects	40	18.35%
	Some projects	44	20.18%
	No projects	134	61.47%
Do you use CDE on projects?	Yes	76	34.70%
	No	143	65.30%

Exchange Information Requirements (EIR) means that the model is in most cases inappropriately prepared for further use, and it is necessary to undertake many modifications before it can be handed over, which represents unnecessary additional costs [67–69].

For effective and clear communication across the project, BIM managers and coordinators have the administration and management of CDE within their scope of work. If we look at BIM from a process point of view, CDE is used today by 35% of active BIM users in Slovakia, which represents less than 5% of the projects on the market. This implies that in most BIM projects (65.3%), the communication on the BIM project and the handover itself, whether interim or final, takes place outside CDE. This form of communication is proven inefficient and often leads to errors in coordination within the project team, as well as within the individual tasks associated with the revision, comments, and determination of requirements. The ratio of projects using CDE is shown in Table 8.

As already mentioned above, the number of BIM projects grows on a yearly basis; therefore, the experience of individual participants in the life cycle grows. More than 34% of active BIM users today declare six or more years of experience, while only 12.56% of respondents admitted one year of experience. The survey also shows that the majority of active users are advanced experts who adopt a collaborative approach and use BIM on their own initiative. The request for BIM is generally still at low levels but growing every year. In 2017, the level of personal initiative for using BIM was 74%, but in 2022 it was approx. 4% lower (68.61%), which is interconnected with the rising requirements mainly from the employer (21.52%), a business partner (8.52%), or the superior institution (1.35%). The last case usually concerns international companies that have a mother unit based in a country with a higher usage of BIM. The details are presented in Table 9.

Table 9. Level of BIM expertise and motivation.

BIM Expertise and Motivation		No. of Participants	Percentage of Participants
How advanced you are using BIM?	Beginner	57	25.56%
	Advanced	124	55.61%
	Expert	42	18.83%
How long do you use BIM?	1 year	28	12.56%
	2–3 years	67	30.04%
	4–5 years	52	23.32%
	6 or more years	76	34.08%
What is your motivation?	My own initiative	153	68.61%
	Request from the employer	48	21.52%
	Request from a business partner	19	8.52%
	Request from the superior institution	3	1.35%

4.3. Third Part of the Survey

The last part of the survey applies to all respondents, both those who already use BIM and those who do not. Three questions are formulated, aiming to identify the demand for BIM, and expectations for the future in regard to BIM adoption in the company of the respondent. The last question contributes to the identification of the barriers associated with BIM implementation.

The survey reveals that there is a low demand for BIM even at the inter-company level. Only 8.98% of companies require BIM from their suppliers in the supply chain, and up to 68.34% state that they have never received a request for BIM delivery. An overview of the requirements is presented in Table 10. We can conclude that this phenomenon is caused by a lack of experience and a lack of qualified decision-taking personnel. The number of cases where BIM implementation reached the practical use of the model on the construction site is therefore relatively still low.

Table 10. Demand and future development.

Demand and Future Development		No. of Participants	Percentage of Participants
The status of request on market	We are NOT receiving request for BIM	723	68.34%
	We do not require BIM	189	17.86%
	We are receiving request for BIM	198	18.71%
	We require BIM from our suppliers	95	8.98%
When do you expect to use BIM?	We already use BIM	275	25.99%
	We do not expect to ever use BIM	404	38.19%
	We expect the implementation within 5 years	224	21.17%
	We expect the implementation within 2 years	103	9.74%
	We expect the implementation within 1 year	52	4.91%

Based on the data from the survey, BIM adoption in Slovakia shall rise in the horizon of 5 years according to 61.81% of respondents, while 9.74% anticipate implementation in the horizon of 2 years, and 4.91% in the horizon of 1 year; 38.19% respondents do not expect to ever use BIM.

The difference in the number of the average value of BIM adoption for the year 2022 (21.1%) and the value in Table 10 (25.99%) is caused by a different form of answer. In question 6, which evaluates the current use of BIM, the survey participants are instructed to answer for themselves, not for the company in which they work, whereas in question 14, which evaluates the estimate of implementation in the following period, they answer at the company level. It can be, for example, the CEO, who answered negatively on behalf of himself, as he himself does not use BIM. However, when asked about future use, replied that they are already using BIM in the company.

At the end of the survey, the last question of the questionnaire is focused on barriers to BIM adoption in Slovakia. There are six predefined options that include the most reported barriers identified by the survey authors, as well as the option to list other barriers. In this question, the respondents could choose multiple options; therefore, the sum of the individual listed categories is not 100%.

Missing standards and recommended workflows were selected as a biggest barrier by 40.0%, followed by price (38.3%), the lack of engineering professions (32.3%), and the lack of time (32.3%). These four categories were chosen by more than 30% of respondents. The details on these and other answers are presented in Figure 10.

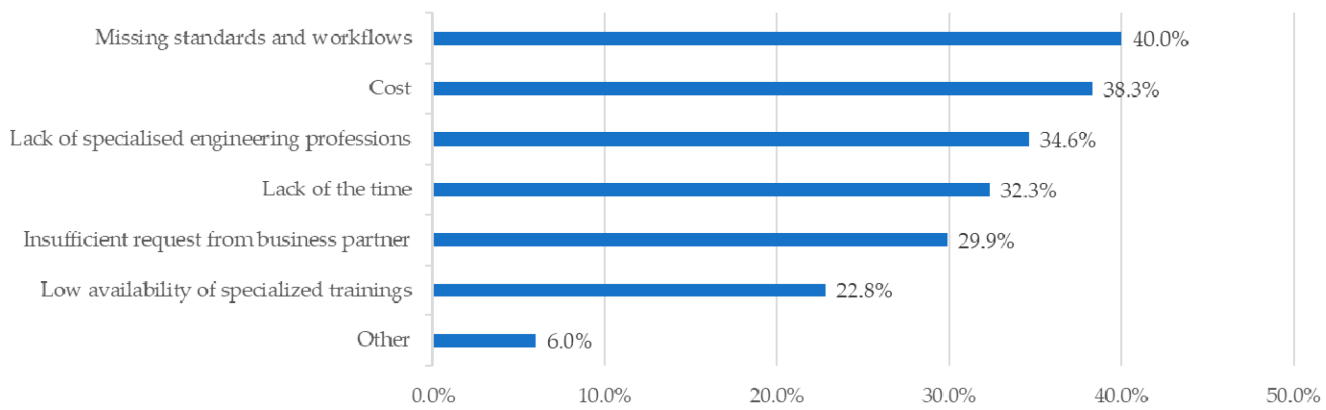

Figure 10. Barriers associated with BIM adoption.

It comes as no surprise that missing standards and workflows, as well as the cost of implementation, are the two most prominent limiting factors, closely followed by the shortage of specialized engineering professionals and the lack of time for BIM implementation. Standards and workflows are indispensable for BIM implementation due to their role in establishing a meticulously structured framework for data interchange, synergistic collaboration, rigorous quality assurance, and heightened efficiency. These foundational elements are instrumental in fortifying BIM as a dependable and potent instrument for the conception, construction, and governance of building and infrastructure undertakings.

The cost of BIM solutions plays a pivotal role in prudent financial management, resource allocation, competitive positioning, and strategic decision-making when it comes to technology adoption. The absence of a straightforward ROI assessment for BIM implementation and the lack of comprehensive cost–benefit analysis pose critical challenges to the adoption of BIM. Addressing these issues is paramount, as it allows organizations to clearly evaluate the financial investment vis à vis anticipated benefits. This, in turn, would enable them to harmonize BIM implementation with their strategic goals, project needs, and the allocation of human resources, especially in the demanding time-pressured context of ongoing projects.

5. Theoretical Contributions

The present paper holds the potential to contribute significantly to the theoretical foundations of BIM and digital technology adoption in building project lifecycles, and to the related cross-regional comparative analysis. Specifically, our research can make theoretical advancements in the realm of the BIM Technology Acceptance Model (BTAM), offering valuable insights into how the construction industry perceives and embraces technology. We also aim to shed light on the primary factors that influence IT adoption and usage, drawing inspiration from the Diffusion of Innovation Theory pioneered by Everett Rogers.

Furthermore, our research recognizes the importance of incorporating cultural and specific economic dimensions into the theoretical framework. These aspects can exert a profound influence on patterns of IT usage and attitudes toward technology. It is worth noting that these considerations may vary across different regions, which underscores the need for a nuanced, region-specific analysis.

In terms of applicability, we have already demonstrated the adaptability of our approach across various geographical and economic contexts (implementation in other countries, such as Italy, Slovenia, etc.). Our methodology can serve as a foundational framework for crafting survey questions that are not only flexible but also maintain comparability and repeatability across different environments.

Incorporating these theoretical underpinnings into IT use surveys holds immense value for both researchers and practitioners. It enables a more profound comprehension of the motivations behind individual and organizational technology adoption and utilization. These theoretical frameworks provide a robust basis for designing surveys, interpreting survey findings, and devising strategies to enhance the effective adoption and usage of IT solutions in diverse settings. This holistic approach ensures that IT implementations align with the specific needs and cultural nuances of the regions they serve, fostering successful outcomes and sustainable technology integration.

6. Conclusions

Based on the research presented in this paper, we provided key criteria for the comparative analysis and better understanding of the specifics of the status of BIM adoption in Slovakia. Carefully collected and analyzed data from the period 2017–2022 proved to be instrumental in providing evidence-based factors that determine the general overview of the readiness of the construction industry to implement BIM.

A comprehensive literature review contributed to the in-depth understanding of the concepts, benefits, and challenges associated with BIM adoption in the global construction industry, providing a solid foundation and a baseline for a possible comparative analysis in the future. This study not only contributes to BIM and digitalization benchmarking, but also provides valuable information to digitalization policy makers at the governmental and construction business levels, who may use the identified key criteria as the input to the national strategy for BIM implementation and related digitalization. The key criteria include, but are not limited to, areas of BIM use, the level of BIM maturity, and specific factors influencing BIM adoption.

We can conclude that both qualitative and quantitative research methods cumulatively provided a well-rounded understanding of BIM adoption in Slovakia's construction industry. In particular, a large-scale sample of stakeholders from the industry provided representative criteria and perspectives on BIM adoption along with major challenges, which are process-specific.

Diverse aspects with specific goals and objectives can only be obtained if the data are collected from diverse sources covering different roles in the industry, including construction companies, government agencies, industry associations with different organizational structures (e.g., small contractors, large firms), and type of practitioners (e.g., architects, engineers, contractors), with a wide coverage of project types (e.g., residential, commercial, infrastructure) across lifecycle phases. The analysis of the above-mentioned collected data can really serve to determine the extent of BIM adoption in Slovakia's construction industry. Although the conducted survey surpasses most other noteworthy surveys in terms of respondents per capita or per total revenue of the national construction industry, we are aware that there may be areas of construction industry or projects that are not represented.

In 2022, the adoption of BIM in Slovakia reached 21.1%, with the highest use in buildings 27.8%, compared to only 8.8% in infrastructure (note that the number of buildings and infrastructure projects is not the same). Based on the results from the first part of the survey, we can see that the typical respondent is an architect/engineer from a micro-enterprise in Bratislava who designs buildings. The low utilization of BIM in infrastructure may be attributed to the fact that most infrastructure projects are executed by large contracts and are publicly funded, for which there is no BIM mandated [2]. The adoption rates across project stages are also interesting: 29.1% use BIM in design and 41.3% in the follow-up development, that makes them both above average.

We can also conclude that the results, at least at large, confirm the findings regarding the reasons for BIM adoption in other countries. Interestingly, 68.61% of respondents adopted BIM based on their own incentive, and 68.34% interviewees never even received a request for BIM. At the time of writing, only 8.98% have an explicit requirement for BIM. Slovakian companies adopt BIM to increase quality and work efficiency and to better manage complex projects, which provides a valuable insight into the national strategy.

From the perspective of occupation, structural engineers (33.3%) are among the most developed professions, followed by architects and other engineers (28.9%). When assessing their maturity and skills, 18.83% of them are experts, handling open data-based exchange and implementation in a wider team, while 34.8% have six or more years of experience. New positions on a market are emerging—BIM managers and BIM coordinators were represented by 3.40% in 2022. The number of BIM professionals is gradually rising accordingly. Among other tasks, BIM managers and coordinators are responsible for the preparation of BEP, a key document for BIM delivery. Interestingly, 18% of BIM projects in Slovakia have BEP, while 35% use CDE for project communication and collaboration.

Based on the survey results, the main barriers for BIM adoption were identified as being missing standards and workflows (40.0%), price (38.3%), and a lack of engineering professions (34.6%). Although, at a company level, many standards are evolving and put to practice, it is rather important to introduce national standards and workflows.

Despite the fact that BIM adoption is growing gradually over the years, survey reveals several interesting results. According to a report [23], 72% of contractors in the US were using BIM on-site already in 2012, declaring significant cost savings in various projects, while this survey reveals that BIM use by contractors in Slovakia is very low even today, reaching 11.3% in 2022. An interesting fact is revealed when comparing the situation in the category of professionals not interested in BIM. According to [6], this category has decreased in the UK to 1% (2020). Slovakia, with this category represented by 46% in 2022, would approximately fall 11 years behind the UK.

Finally, the survey reveals that 61.81% of respondents estimate that they will start using BIM in the horizon of 5 years, but it is important to keep track of developments in the industry to see how BIM adoption evolves over time. This can help measure the impact of proposed recommendations in the future. Sharing this research can help raise awareness and promote BIM adoption in this region and beyond.

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Conflicts of Interest: The authors declare no conflict of interest.

Nomenclature

BEP	BIM execution plan
BIM	Building information modeling
CDE	Common Data Environment
EIR	Exchange Information Requirements
EU	European Union
IFC	Industry Foundation Classes
HVAC	Heating, ventilation, and air conditioning
MEP	Mechanical, electrical, and plumbing
STN	Slovak technical standard
SMEs	Small and medium-sized enterprises
OECD	Organisation for Economic Co-operation and Development

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