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The Role of Organizational Learning and Knowledge Management for Successful BIM Integration in Lighting Design

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Abstract. Building Information Modeling (BIM) is increasingly shaping building design and construction processes, but its implementation in lighting design remains a challenge. To identify the challenges and derive solution strategies, two large-scale online questionnaires were conducted among stakeholders, particularly from industry, planning, research, and development. The results show that although BIM is perceived as highly relevant, its integration into daily practice is subject not only to technical limitations, such as insufficient interoperability, but also, in particular, to resistance in the organizational culture. This study focuses on the role of organizational learning and its necessity to ensure long-term implementation. In addition to technological change, the introduction of BIM also requires continuous organizational learning processes that harmonize individual skills with collective structures. The results of the study emphasize that the introduction of BIM is not only associated with technical challenges, but also with organizational changes.

Keywords: Building Information Modeling (BIM), Organizational Learning, Lighting

1. Introduction

1.1 BIM as an infrastructure of construction

Driven by information technology, whose exponential progress seems to follow Moore's Law, technical possibilities are growing rapidly [1]. This accelerated pace sometimes contrasts with the traditional construction industry, which is characterized by long-term project cycles, numerous players, and complex structures, and is one of the least digitized sectors [2], [3], [4]. Yet digitalization in the construction industry promises advantages such as improved planning, waste reduction, error minimization, and increased productivity [5]. The construction industry is therefore currently facing the challenges of far-reaching digitalization, which is changing not only its tools but also its ways of thinking and working [6], [7]. The necessary change is unfolding at both the technical and organizational levels, challenging old practices and demanding new forms of cooperation and knowledge organization.

Building Information Modeling (BIM) is a central concept in the digitalization of the construction industry. BIM not only provides digital models, but also enables the integration of information, which promotes and supports the networking of the parties involved and the transformation of processes throughout the entire life cycle of buildings [6]. The working method is proving to be not only a technological innovation, but also a comprehensive approach, a new epistemic order that opens up the possibility of overcoming the limitations of fragmented information and knowledge management. BIM is thus becoming a catalyst for fundamental change in a previously slow-to-adapt industry and can be understood as an instrument for rationalizing and systematizing knowledge (cf. [3]). Across all phases, BIM enables more precise analyses, sustainable designs, improved resource utilization, and the optimization of operation, maintenance, and servicing, with advantages in terms of cost and energy efficiency [8], [9]. It is therefore not surprising that the advantages of BIM are increasingly being recognized, which is reflected in its increased use [8], [10].

BIM integration affects all areas of construction, from planning and construction companies to facility management (FM), but its introduction is not uniform across organizations and areas of application [4], [11] and is generally still somewhat hesitant [12]. High costs, security requirements, interoperability, and lack of compatibility complicate the implementation of new methods such as BIM and pose key challenges [2], [9], [13]. However, it is not only technical hurdles that limit its use; organizational fragmentation and cultural resistance also hinder implementation [11]. Differences in digital skills and organizational maturity shape the perception and acceptance of BIM and can have a direct impact on necessary transformation processes. From an organizational science perspective, the successful implementation of innovations is closely linked to the organization's ability to initiate learning processes, collectively mobilize knowledge, and critically reflect on established routines. The integration of a digital technology such as BIM is therefore not determined solely by its technical feasibility, but by the dynamic interaction between organizational learning ability, cultural openness, and adaptive redesign of structures and processes [7], [11].

Since full implementation of BIM will mostly likely bring advantages, competition is created. Organizations are therefore focused on self-preservation in dynamic environments, such as those driven by digitalization, whereby this function relates to the continued existence of the organization as a whole [14]. Planning offices are more compelled to systematically expand their capabilities in order to remain competitive with digital tools, while construction companies are under less pressure to acquire new digital skills because their focus is on physical production rather than virtual design [4]. However, the use of computer-aided manufacturing also results in economic advantages in execution [15], [16]. To ensure competitiveness, they are dependent on continuous learning processes, the active use of which strengthens the adaptability and thus the long-term success of the organization. Success therefore requires a rethinking of processes, structures, and collaborations, as well as the ability to learn adaptively [14]. There is a discrepancy between technical rationality and operational processes within the organization, which is addressed through learning processes and collective adjustments. The implementation of BIM thus becomes a learning process for the organization, combining the goals of construction practice with the dynamics of organizational knowledge formation.

1.2 Organizational learning processes as the basis for institutional development

A learning process can only be initiated if members of the organization have the relevant qualifications, i.e., knowledge of the relevant procedural processes [17]. This learning process is transferred to all individuals involved through internal organizational communication. Since knowledge transfer is a social interaction process, it is subject to a variety of individual cultural and structural influences. The organizational level, which encompasses all the necessary methods, mechanisms, processes, and structures of learning, acts as a mediating element, while the organizational level of knowledge shapes the development of individual skills [18], [19]. The organization itself therefore learns through the completed learning process of all individuals. Organizational learning thus arises at the individual level and is transferred to the organizational level through organizational structures. This transition causes structural changes, which in turn have an impact on the thinking and actions of the organization's members. There is an interaction between the organization and individuals in which both individual learning processes and the organizational framework and collective knowledge are transformed [18], [20]. Therefore, both levels must always be taken into account in the implementation process of a new technology.

The organization's ability to transform itself in order to adapt to and anticipate any changes in the environment, such as competition-related digitalization, is largely based on its organizational learning ability. The potential of the organization's stored knowledge, or organizational intelligence, is directly dependent on its organizational agility to adapt to new requirements. Organizational learning can therefore be understood as a reactive and purpose-oriented process of adaptation to external influences that takes place at the internal structural and contextual level of the organization. It serves to continuously renew organizational structures and ensure organizational capacity to act [14], [21].

1.3 Objective of the work

The literature shows a discrepancy between the perceived importance of BIM and its practical implementation [11]. The implementation of BIM requires not only fundamental technological change but also organizational change within the AECO industry (Architecture, Engineering, Construction, and Operations). The objective of the study is to collect and secure empirical findings on the current challenges, stakeholder perceptions, and effective measures for overcoming obstacles to BIM implementation. This study focuses on organizational transformation processes and their necessity to ensure the long-term establishment of the planning method within the organization. Particular attention is paid to the interaction between individual and organizational learning processes, as BIM implementation is not a one-off project but a continuous transformation cycle. By combining empirical results from two extensive market surveys with a conceptual perspective on organizational learning, the study contributes to understanding how the construction industry can develop adaptability and meet the requirements of increasing digitalization. This study also focuses on lighting, which, alongside HVAC, is one of the most significant energy consumers [22]. Accordingly, the survey participants are limited to the lighting industry. This work continues the research of Hammes et al. on BIM implementation (see [11]) and presents new findings with a focus on organizational learning.

2. Related Work

An evaluation of the literature on BIM reveals not only technical limitations such as insufficient interoperability, but also organizational challenges that restrict the introduction of BIM, despite its proven advantages [3], [9], [11], [12]. Hsieh et al., for example, conducted a survey of the Taiwanese construction industry to investigate the direct and indirect effects of digital transformation. The results from over 300 responses identify significant effects on project management optimization. The impact depends crucially on how well organizations develop complementary skills such as agility and knowledge management. Organizational agility in particular proves to be essential for adapting quickly to change, reconfiguring resources, and remaining responsive. The results show that digitalization measures can only be considered sustainable and successful if they are understood as strategic change and linked to appropriate leadership, cultural, and organizational structures [7].

Change management refers to the planned and targeted design, control, and support of transformation processes in organizations and their structures. In this context, the study by Ba et al. examines strategies for overcoming barriers to the implementation of BIM in FM applications. Based on a comprehensive literature review of the challenges of BIM implementation, the authors develop a roadmap for the necessary change management within the organization. The roadmap covers, in particular, team organization, formulation and planning of the change process, management of implementation, and ensuring sustainability and continuous improvement. The results show that the structured approach enables organizations to make an effective transition to BIM use and reduces individual and organizational resistance [23]. Resistance usually stems from a lack of acceptance of the technology. It is therefore essential to take measures within the organization to promote acceptance [24]. Acceptance of BIM can be promoted through targeted knowledge transfer and practical training measures, with self-directed learning and internal training being preferred. In addition, managers play a central role by not only supporting implementation, but also actively creating a learning-friendly corporate culture and establishing clear, realistic BIM goals within the organization [11]. Related studies show that the establishment of BIM depends not only on technical requirements, but also on organizational learning, acceptance, and the ability to establish new cooperative and knowledge-based forms of work.

3. Methodology

Two questionnaires with different objectives were used to answer the research questions. The first questionnaire focused on technical challenges associated with the application of BIM, while the second addressed organizational framework conditions and related challenges. The separation into two instruments was made in order to map the different levels of analysis in a targeted manner and with appropriate indicators in each case. The two questionnaires were combined into a joint study in order to analyze the interactions between technical and organizational aspects. This enables an integrated view of the technical and organizational challenges without sacrificing the analytical precision of the individual dimensions.

3.1 Organizational dimensions of BIM (Questionnaire 1)

To gain an understanding of the problem and derive possible solutions, a survey was conducted that primarily addressed organizational framework conditions, experiences and challenges, as well as individual and organizational knowledge and related training and qualification measures (see [11], [25], [26]). The survey was advertised between May and July 2024 via German-speaking lighting societies (LTG and LiTG via website, newsletter, and mailing lists). In addition, participants were recruited via social media channels and mailing lists of the licht.de knowledge platform. Participation was voluntary. The survey was available exclusively online and in German (implemented via TIVIAN). The number of questions was linked to the respective specialist knowledge of the participants (min: 20, max: 63 questions) in order to counteract the risk of dropouts. For the same reason, different question formats were also used. 72 responses were complete for evaluation. Of these, 83.33% came from Germany, 11.11% from Switzerland, 4.17% from Austria, and 1.39% from Italy. 69.44% of participants are planners, 22.22% are in the manufacturing industry, and 8.34% are in other areas. In their self-assessment, 8.33% of participants identified themselves as BIM experts, 15.28% as having advanced knowledge, 29.17% as having basic knowledge of the subject, 37.50% as having little knowledge, and 9.72% as having no prior knowledge of BIM.

3.2 Technical dimensions of BIM (Questionnaire 2)

Digital technologies such as BIM represent an external influencing factor that organizations must address. To ensure successful BIM implementation and realize its potential, an integrated approach is needed that combines technological innovation with organizational learning in collaborative structures [11]. Therefore, in addition to understanding organizational challenges, a thorough assessment of technical challenges is necessary. The second survey therefore focuses specifically on the technical aspects of BIM in planning and operation, again with a focus on lighting (see [11], [13], [27]). The survey was available from March to September 2023 and November to February 2024. It was implemented using LimeSurvey. Once again, a mix of different question types was used, and respondents were given the option to skip questions in order to keep dropout rates low. Unlike the other survey, this one was available in German and

English. In German-speaking countries, it was primarily advertised through lighting associations (LTG, LiTG via website and newsletter) and internationally through the CIE, AIDI and IEA Task 70 (mailing lists and social media). Participation was also voluntary. 123 responses were available for evaluation. Responses from the target groups in the areas of facility management and building owners were excluded in advance, as the associated questions are not covered by this evaluation. Of the 123 responses used, 37.40% came from Austria, 11.38% from Italy, 10.57% from Germany, 24.39% from other EU countries, and 16.26% from outside the EU. 36.59% of participants are from research and development (R&D), 34.96% are planners, 21.14% are from the manufacturing industry, and 7.31% are from other areas. Almost all participants are familiar with BIM. 48.78% rate BIM as moderately to highly relevant, while 43.90% consider it to be of little to no relevance. 7.32% are not familiar with BIM (see [11]).

3.3 Statistical evaluation

The survey results were analyzed descriptively and using statistical methods in order to derive solutions for the necessary transformation process for successful BIM implementation and to highlight the role of organizational learning. The methods used were primarily χ^2 tests and logistic regression analyses. This method enabled the identification of key predictors for BIM implementation. χ^2 tests report the p-value (significance), the χ^2 value (magnitude of the difference between observed and expected frequencies), and the degrees of freedom (df, number of independent information). Logistic regressions report β (regression coefficient, direction and magnitude of the effect), p-value (significance), OR (odds ratio, effect size), LLR-p (likelihood ratio test for the overall model), and Pseudo-R^2 (explained variance or model fit). The statistical analyses were performed with JASP (version 0.19.1.0) at a two-sided significance level of 0.05 and supplemented with Python 3.12.

4. Findings and Discussion

4.1 On the teleology of organizational learning in the context of BIM (Questionnaire 1)

The literature has shown that a rethinking of processes and internal organizational structures, as well as organizational learning, is initiated in particular by external influences that are necessary to ensure competitiveness [14]. In this context, the survey results show that project specifications (73.91%) are considered the biggest external factor influencing the use of BIM. 13.04% cited self-interest as the reason for switching. 8.70% of participants work in companies where BIM is already established as the planning standard (other influences 4.35%; question type: multiple choice, normalized to all responses).

BIM requires profound structural and cultural change processes within organizations [11]. The structural reorganization of processes is rated as challenging to very challenging by survey participants (see *Figure 1*). The process of acquiring the necessary knowledge, adapting actions accordingly, and establishing this within the organization begins with individual learning and is influenced by organizational structures and their support options (cf. [18], [19]). Training and employee development accelerate the learning process. The survey shows that 33.84% acquire BIM through self-study. Organizations can only support this by granting time off work. 26.16% resort to paid learning measures and 35.38% to free measures (other: 4.62%; question type: multiple choice, normalized to all responses). Training courses can prove to be costly and time-consuming, which is particularly difficult for smaller companies to finance. 44.83% of respondents would like to see more training (no need: 13.79%, no response: 41.38%, question type: single choice). In order to promote BIM in the long term and establish it in practice, it is advisable to expand its use in public and free offerings and in university teaching (cf. [8]).

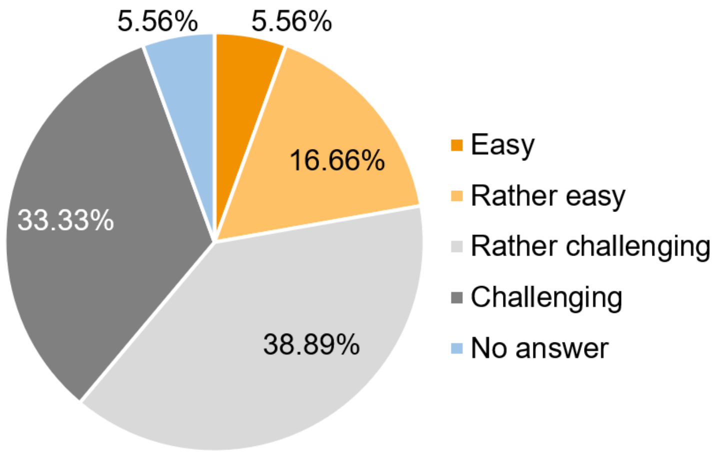

Figure 1. *Assessment of structural change through the use of BIM (question type: Likert scale, valid responses: 18).*

Individual and organizational learning are recursively interrelated [18]. Individual learning is based on the acquisition of knowledge through the modification of old cognitive structures. The newly acquired knowledge can be accessed for future action. The individual's repertoire of skills increases. Organizational learning is based on communication between individuals, which ultimately results in the distribution of knowledge. Knowledge is distributed via structures that are in turn changed in the context of individual learning [20]. They can therefore be seen as complementary functions in the development process.

Among the participants, knowledge of BIM ranges from none to expert level, both individually and organizationally (see *Figure 2*). A chi-square test shows no significant correlation between the results at the individual and organizational levels ($\chi^2=0.81$, $p=.93$, $df=4$, referring to *Figure 2*). Another chi-square test shows that the perception of measures is significantly related to BIM knowledge. This applies to both the individual ($\chi^2=4.08$, $p<.05$, $df=1$) and organizational levels ($\chi^2=6.75$, $p<.05$, $df=1$). Although a logistic regression indicated a tendency toward a positive effect of the number of learning measures on BIM knowledge, the effects were not statistically significant for either participants' individual knowledge ($\beta=1.03$, $p=.07$, $OR=2.81$, LLR-$p=.04$, Pseudo-$R^2=0.12$) or organizational knowledge ($\beta=0.52$, $p=.34$, $OR=1.68$, LLR-$p=.33$, Pseudo-$R^2=0.04$).

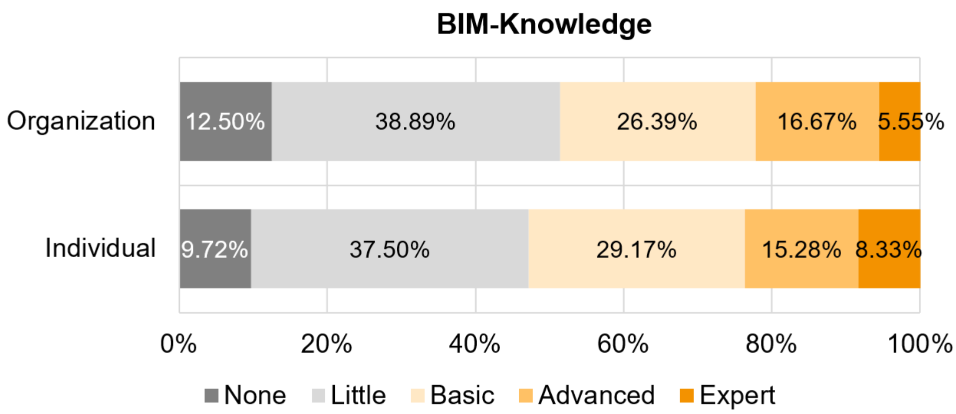

Figure 2. *Level of knowledge of BIM at individual and organizational level (question type: single selection, 72 valid responses).*

The results show that the mere existence of measures has a significant correlation with BIM knowledge at both the individual and organizational levels. The number of measures, on the other hand, does not significantly influence knowledge, suggesting that it is not the quantity but the existence and possibly the quality of the measures that matters. The implication for organizational learning is that organizations should focus on implementing targeted learning measures, as the mere existence of such measures strengthens the individual knowledge base. For organizational learning, this means that resources should be used strategically to promote sustainable learning processes rather than simply increasing the quantity of training measures. Training courses tend to be considered effective in familiarizing employees with the BIM planning method (Yes: 26.67%, mostly yes: 40.00%, mostly no: 20.00%, No: 0.00%, No response: 13.33%, Question type: Likert scale). Organizational learning in BIM implementation occurs when training knowledge is transferred into new roles, structures, and decision-making processes, thereby replacing existing thought patterns with profound, accommodative changes. A suitable organizational structure based, for example, on clear communication channels and institutionalized learning platforms can enable individual knowledge to be transferred to organizational standards and practices.

The acquisition process oscillates between the area of knowledge management, or the cognitive dimension, and the dimension of emotion, which is subject to the company's social and cultural framework of values and norms as well as the intrinsic motives of individual employees. The working environment and interpersonal factors are summarized here, but they are directly interrelated. The commitment of the organization's members is crucial to establishing learning as an ongoing task and thus harnessing the potential of BIM within the company. The first step is to create acceptance for the topic. The survey shows that within the participants' organizations, there is a mixed picture regarding the acceptance of BIM (no to little acceptance: 33.33%, moderate to high acceptance: 37.50%, no statement: 29.17%; question type: Likert scale).

The knowledge gained is disseminated via internal communication structures, informal learning, and organizational meetings. Through this dialogue, assumptions are reviewed, adjusted, and anchored within the organization. Organizations must view this as a continuous learning process and adapt agilely to technological, cultural, and structural changes. The rapid development of machine learning methods in various areas of application is currently encouraging organizations to learn, adapt structures, and evolve, and this trend is set to intensify in the future (see [28]).

The evaluation also shows that the majority of respondents use BIM only to a limited extent (median: 20.00%, mode: 10.00% (discrete selection of available characteristics)). Over 50% of the responses indicate BIM use of ≤20% (see *Figure 3a*). BIM is therefore predominantly used selectively or sporadically, but not across the board. This is confirmed by the responses regarding existing BIM departments in companies (No: 83.33%, Yes: 16.67%). Corresponding positions such as BIM overall coordinator and specialist coordinator, author, and user are also predominantly not available (>60%). These results indicate an early to medium level of maturity in BIM implementation. BIM does not yet appear to be established as a consistently integrated working methodology in many companies, but is primarily used in specific areas or pilot projects. This may indicate that the respective organizations are still in an introductory phase and are initially testing new digital methods in a risk-minimizing manner. With regard to project size, a contrasting trend can be observed (see *Figure 3b*). Around 50% of the responses relate to projects with a volume of ≥€30 million, while small projects (<€5 million) play only a minor role. It should be noted here that BIM use is primarily based on external project specifications (73.91%, beginning of section 4.1). This suggests that BIM is used in particular where project complexity, coordination requirements, and economic risks are high. Large projects benefit more from improved coordination processes, collision checks, and transparency throughout the entire project lifecycle. To test this, the project size was set as a function of the reasons for using BIM. The chi-square test performed did not reveal any statistically significant correlation between project size and reasons for using BIM (χ^2=3.05, p=.80, df=6). However, the effect size according to Cramér's V (V=0.26) indicates a weak to moderate correlation. Due to the small sample size and low expected frequencies, the significance of the test is limited. Nevertheless, descriptive statistics reveal differences that indicate a stronger strategic motivation for BIM use in larger projects.

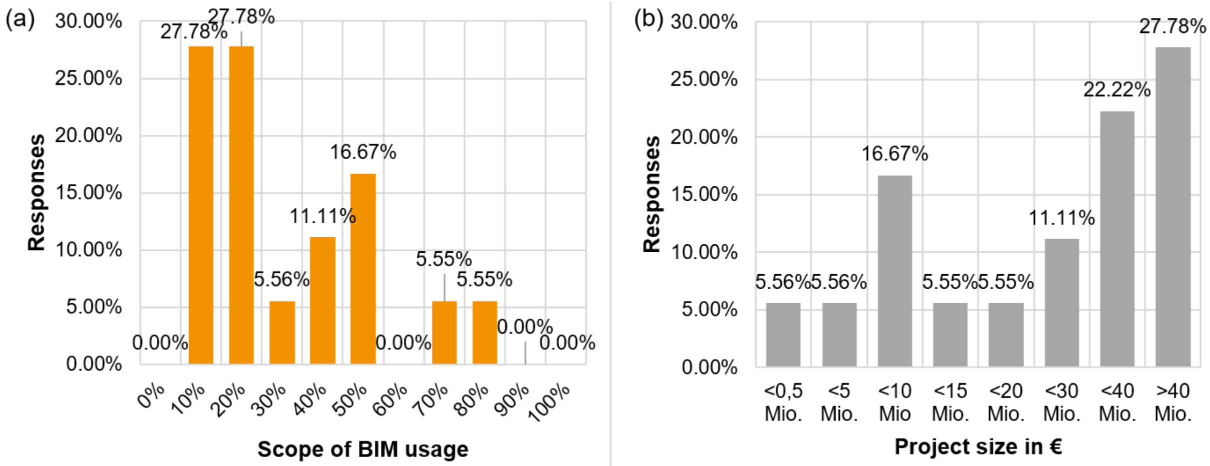

Figure 3. *Feedback on the extent of BIM use (a) and the project size of those construction projects in which BIM is used (b) (question type: single selection in each case, 18 valid responses).*

The assessment of profitability is predominantly critical. 50.00% of companies rate BIM projects as less profitable, while 22.22% were unable to provide any information. Only 5.56% report higher profitability, and 22.22% see no change. These results indicate that many companies have not yet realized the economic benefits of BIM. The results suggest that many organizations are still in the exploratory learning stage, gathering experience, adapting processes, and building skills. The assessment of profitability can then be attributed to the fact that many of the participating organizations are currently in the early stages of engaging with BIM and are not yet making full use of it, and are therefore facing high start-up costs for training, software, process adjustments, and coordination [11], [13]. Most participants are aware of the investments that would be required to introduce BIM (completely clear: 15.38%, mostly clear: 61.54%, mostly unclear: 15.38%, completely unclear: 7.69%). Another aspect that may contribute to this attitude is that the additional costs of BIM planning, due to fragmented involvement in different areas, are not always associated with the realization of benefits and therefore also require changes in the legal situation [11].

The introduction of BIM involves both organizational and technical challenges that are closely interrelated, which will be analyzed in more detail in the second survey. The majority of survey participants perceive BIM as complex. 11.76% of participants strongly agree with this statement, 41.18% somewhat agree, 29.41% somewhat disagree, and 17.65% strongly disagree. At the same time, the maturity of the technology is also viewed critically (strongly agree: 12.50%, somewhat agree: 32.25%, somewhat disagree: 31.25%, strongly disagree: 25.00%). This parallel perception suggests that technical shortcomings, such as a lack of standards or immature tools, can increase organizational complexity, while conversely, unclear processes and a lack of routines make it difficult to use the technology effectively. The introduction of BIM should therefore not be understood as a purely technical implementation project, but rather as an organizational change process in which technical and organizational challenges reinforce each other and must be addressed jointly.

4.2 BIM between technical rationality and organizational learning (Questionnaire 2)

Even though BIM offers numerous advantages [8], [9], [13], several challenges have been identified (see *Figure 4*). In particular, insufficiently trained personnel is identified as a challenge. This aspect is influenced by the organizational structure. With cost being the second biggest obstacle, a connection can be assumed here. In addition, technical difficulties arise when linking different planning and simulation software due to a lack of interoperability.

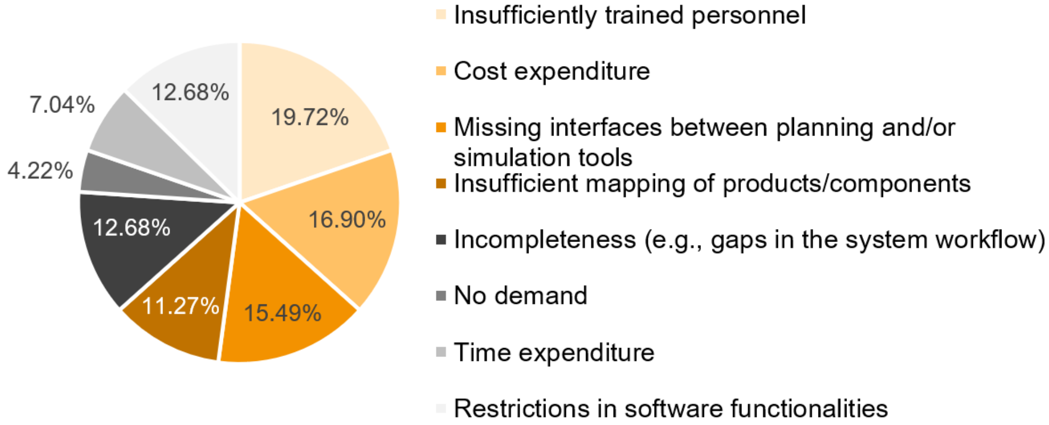

Figure 4. *Challenges in BIM usage (question type: multiple choice, normalized to all responses, 71 valid responses).*

According to Ipe [29], knowledge acts as an interface between the individual and organizational levels, i.e., no organization can exist without input from individuals. Social capital can facilitate access to necessary information and create new knowledge [30]. An organization with strong social capital can therefore have greater access to information and achieve more innovative results [31]. With regard to the participant field, it can be seen that feedback was predominantly provided by large companies (see *Figure 5*). *Figure 5* shows a slight tendency for relevance to increase with company size. A logistic regression was performed to assess the dependence of company size on BIM relevance. BIM relevance was coded dichotomously. The logistic regression shows a positive but statistically insignificant correlation between company size and perceived BIM relevance (β=0.28, p=.13, OR=1.32, LLR-p=.12, Pseudo-R^2=0.02). Although larger companies often have more resources, formalized processes, and stronger external integration, these structural advantages alone do not seem to be sufficient to systematically classify BIM as more relevant. BIM is therefore perceived as relevant where there are specific application requirements, market constraints, or innovation strategies. Perceptions of relevance appear to be more context-dependent and determined by qualitative factors that are merely favored by company size, but not determined by it.

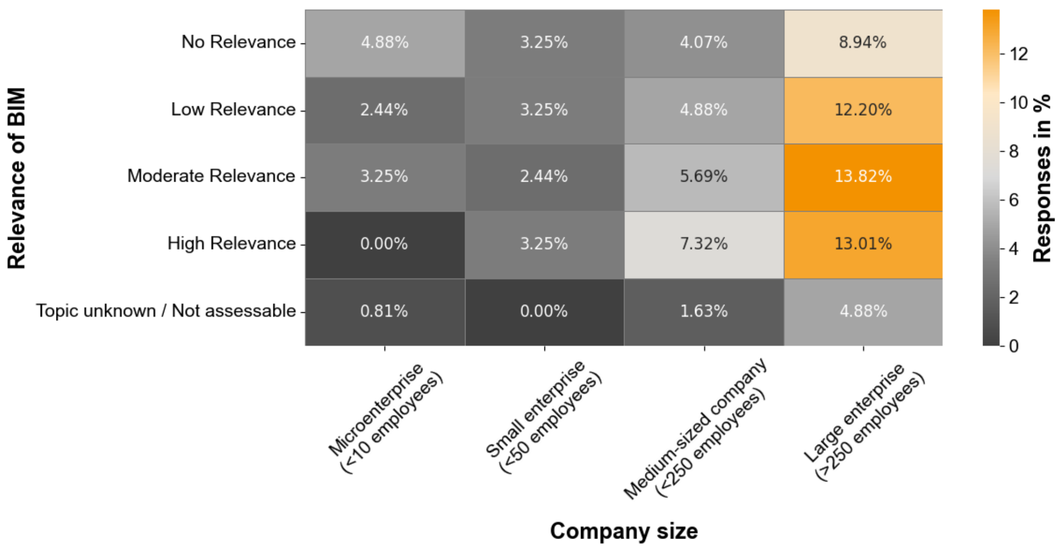

Figure 5. *Relevance of BIM use depending on company size (question type: single selection, 123 valid responses).*

In recent decades, proprietary software systems and incompatible data formats have led to a significant separation between the individual trades in the planning and construction process. These technical barriers have favored sequential, discipline-oriented working methods [32]. BIM challenges this paradigm, as it is based on collaborative, model-based cooperation across disciplinary boundaries. Logistic regression revealed a significant correlation between the number of trades supervised and the use of BIM as a basis ($\beta=0.36$, $p=<.05$, $OR=1.43$, LLR-$p<.05$, Pseudo-$R^2=0.11$). With each additional trade, the probability of BIM use increases.

The introduction of BIM is changing not only the tools used, but also the way we work. This change in working methods in turn has an impact on existing technical and organizational structures by revealing their limitations. This results in a need for structural adaptation. Technical systems, standards, and processes must be further developed in order to effectively support the collaborative potential of BIM. Even though each construction project is unique, they contain recurring patterns when viewed from a broader perspective. Traditionally, planners use these recurring patterns and analogies to previous projects, personal and collegial experience to efficiently complete planning projects. Norms and standards can support this by reducing complex issues to solvable units. New technologies such as BIM are changing these modular structures and require a rethink based on the principle of accommodation. New methods and working patterns must be learned. This includes, in particular, training in new software applications (e.g., BIM authoring tools such as Revit, ArchiCAD, and ACCA [11]) and the associated organizational project management. Since the success of a construction project can be largely determined by the planning stage [33], ensuring a successful learning process is crucial. Well-developed digital structures enable the integration of new technologies such as BIM into organizational knowledge and can ensure survival in a dynamic environment [34]. They promote networking and information exchange along the value chain, increase collaboration and systematic learning [35]. The introduction of BIM illustrates how digital communication options can increase planning efficiency [36].

4.3 Limitations

The descriptive analysis of the two surveys shows that the participants were predominantly planners from German-speaking countries. The results are therefore primarily applicable to this regional and professional group and can only be applied to other countries or disciplines to a limited extent. Since the survey was conducted without remuneration and willingness to participate in online surveys is higher when there is a professional interest (see [37], [38], [39]), a participation bias regarding the participation of individuals with an affinity for BIM cannot be ruled out. In this context, questionnaire 1 indicates that knowledge of BIM varies from no knowledge to expert knowledge.

A key limitation of the study lies in the use of self-assessments to measure BIM relevance. These subjective assessments may be distorted by individual perceptions, social desirability, or differing interpretations of the term BIM, and do not necessarily reflect the actual maturity level or effective use of BIM within the company. Furthermore, potentially relevant influencing factors were not explicitly recorded. In particular, intangible factors such as implicit knowledge, established routines, organizational learning processes, or informal decision-making structures could not be taken into account in the survey. However, these factors could significantly influence how BIM is perceived, evaluated, and implemented in everyday business life and thus explain part of the variance that cannot be accounted for by company size alone.

5. Conclusion

Successful BIM implementation in a planning office goes beyond technical aspects and requires profound organizational changes. The necessary learning process and the associated agility of organizational transformation capability depend on the members of the respective organization. The learning of the organization is therefore inseparable from the learning processes of the individuals involved. At the individual level, organizational learning requires that members have the necessary knowledge and willingness to learn new procedures. In order to create acceptance and knowledge, measures and structures set by the organization are required. Investments in training are beneficial, but cannot always be financed due to time and cost constraints. The speed of organizational change therefore usually depends on the financial resources of the company.

Successfully implemented learning processes at the individual level are elevated to the organizational level via the structures of the organization. Elevation to the organizational level is usually accompanied by structural change, which in turn influences the individuals within the organization. There is a strong interaction between the organization and individuals in the context of organizational learning. The knowledge gained is distributed via internal communication structures. In this context, the promotion of information exchange can be seen as a catalyst for the introduction of BIM. The sustainable benefits of BIM require the active commitment of the organization's members and the acceptance of learning as an ongoing task, whereby organizational learning must be understood as a dynamic process in which even disruptions can provide productive impetus for development.

Against this backdrop, knowledge management plays a central role, as it structures and secures individual and collective learning and makes it usable for the organization. It thus forms an essential basis for systematically supporting and sustainably developing organizational learning processes. The introduction of BIM also formalizes and explicitly documents many aspects that were previously based on social and interpersonal interactions in the planning context and were heavily dependent on intrapersonal and cultural factors. These factors can hinder organizational knowledge transfer and are at least partially reduced by BIM's digital and structured information models. BIM acts as a central knowledge and information base in which planning and operational information, which was previously compiled mainly on an individual basis, is systematically documented and made accessible throughout the organization.

Proper implementation and the resulting benefits require a corresponding level of commitment within the organization. After all, commitment is the key driver of the organizational learning process. It is therefore important to ensure that learning is permanently defined as a task within the organization and that appropriate measures are put in place to promote it.

6. Outlook

The present findings suggest that the relevance and use of BIM cannot be explained solely by technological or structural factors, but is significantly influenced by organizational practices, cultural patterns of interpretation, and informal routines. This opens up considerable research potential beyond established, primarily technology-centered BIM considerations, particularly through interdisciplinary approaches that systematically incorporate social, cultural, and organizational dimensions into the analysis of the digital transformation of the construction industry.

Data availability statement

The list of questions from the questionnaire 1, addressing the organizational dimension of BIM, and questionnaire 2, focusing on the technical dimension of BIM, are both accessible online (see [27], [26], [25]). The answers of the surveys can be provided on request.

Underlying and related material

Additional analyses based on the surveys are available online [11], [13].

Declaration of generative AI and AI-assisted technologies in the writing process

To create this work, the authors used DeepL and ChatGPT for translations, linguistic formulations, and text summarization. After using these tools, the results were reviewed and edited as needed. The authors assume full responsibility for the content of this publication.

Author contributions

Sascha Hammes: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Johannes Weninger:** Writing – review & editing, Project administration, Methodology, Investigation, Funding acquisition. **David Geisler-Moroder:** Writing – review & editing, Project administration, Methodology, Investigation, Funding acquisition. **Johannes Strohm:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Mathias Wambsganß:** Writing – review & editing, Supervision.

Competing interests

Author Johannes Weninger is employed by Bartenbach GmbH and the authors Johannes Strohm and Mathias Wambsganß, are employed by 3lpi lichtplaner + beratende ingenieure. The remaining authors declare that they have no competing interests.

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