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POTENTIALS AND BARRIERS OF IMMERSIVE CONSTRUCTION MEETINGS

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Abstract
Immersive technologies, such as Virtual Reality (VR) and Augmented Reality (AR) become important to improve the efficiency of the construction industry. VR and AR are already in use, particularly in inventory and design. In the construction process and especially in the communication during the construction process, AR and VR are rarely used. First studies show that immersive technologies enable enhanced visualization and interaction, allowing participants to engage with spatial and technical aspects of construction projects in innovative ways. AR provides real-time overlays of digital information on physical environments, improving situational awareness and facilitating on-site decision-making. VR creates fully immersive virtual environments, offering precise simulations that support collaborative problem-solving. Together, these technologies are mentioned to enable better communication, reduce misunderstandings, and improve coordination.

Challenges include the absence of non-verbal communication cues in virtual settings, technological limitations, and the need for user training. Especially in hybrid meetings, VR and AR can help make these meetings more efficient and reduce misunderstandings.

To analyze the impact of immersive technologies on communication in construction meetings, this study investigates the application of AR and VR in construction meetings. Using a SWOT analysis, the research examines the Strengths, Weaknesses, Opportunities and Threats with these technologies in hybrid meetings. Afterwards the results are discussed against expert interviews that were conducted in 2024. With the deductive approach of the SWOT analysis and the inductive approach of the interviews, the results can be validated.

The results of the study highlight the transformative potential of immersive technologies in enhancing collaboration, innovation, and addressing communication barriers in meetings. It also emphasizes the need for further research to optimize these tools for usability and industry adoption. By strategically incorporating AR and VR into meeting workflows, the construction industry can increase efficiency and other benefits in traditional communication.

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Keywords: Augmented Reality (AR), Construction meeting, Digitization, Virtual Reality (VR), Immersive Project Management.

1. Introduction

The construction industry faces the challenge of planning and constructing complex projects efficiently [1]. To achieve this, optimal communication between stakeholders (such as construction managers, clients or experts) located in different places (e.g., office or construction site) is essential. However,

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errors regularly occur due to poor communication, highlighting the need to optimize communication among the stakeholders.

Immersive technologies can contribute to improving communication between the stakeholders. These technologies are also expected to play a vital role in future construction processes [2]. In particular, Virtual Reality (VR) and Augmented Reality (AR) offer promising approaches to enhance visualization and interaction within construction workflows. While VR is already being used for planning and simulation, AR enables real-time overlay of digital information onto physical environments, thereby facilitating decision-making on construction sites. This results in a variety of use cases for VR and AR that can span the entire project lifecycle. Especially in hybrid meetings, immersive technologies could help increase efficiency and enhance collaboration. [3]

Although these technologies have the potential to reduce misunderstandings and improve coordination, they are still rarely used during the actual construction phase and communication throughout the construction process. Against this background, the following paper examines the use of immersive technologies—particularly AR and VR—in the context of construction. In terms of the timeline for applying immersive technologies, this paper focuses on the construction phase, meaning that most of the planning has already been completed and only detailed and execution-specific plans are being developed (see Fig. 1).

There is no universally fixed definition for the division of construction projects into phases. According to the PM Guide [4], a building's life cycle consists of six phases. Other authors [5], however, describe only five phases [6]. This difference will not be discussed in detail here. As shown in Fig. 1, the focus is placed on the execution phase. Particular emphasis is placed on tasks that can be further supported by immersive technologies. These primarily include construction supervision and quality assurance, coordination, documentation and communication, as well as inspection and handover.

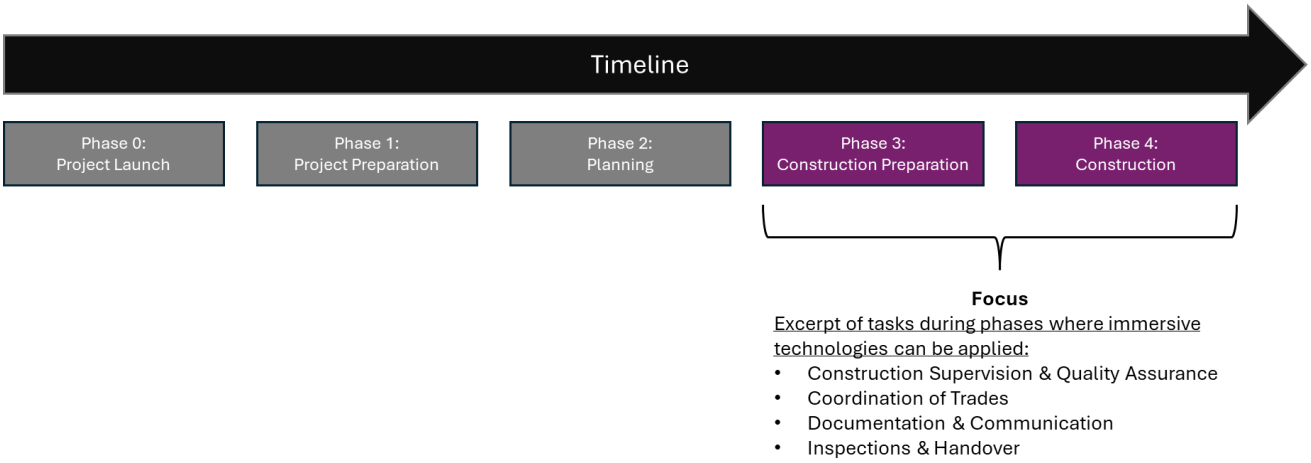

Fig. 1 Timeline of Construction Projects with a Focus on Construction [Own Illustration]

These tasks involve interaction between many stakeholders who engage directly with the building and require a deep understanding of it [7]. In this context, visual support with immersive technologies plays an important role in enhancing communication and comprehension.

2. Related Work

This section outlines the foundations of the paper, focusing on the current state of construction meetings and the definition of immersive technologies.

2.1. Status Quo of Construction Meetings

Construction meetings are a central element in the organization and coordination of construction projects. They serve to structure collaboration among stakeholders and ensure a smooth flow of

information. The goal is to identify and resolve problems as early as possible [8]. A construction meeting can typically be divided into three phases (see Table 1).

Table 1 Phases of a construction meeting [8–11]

Phase	Description
Preparation	To conduct an effective construction meeting, thorough preparation and clear structure are essential. This includes reviewing unresolved issues from the previous meeting and tracking their progress so they can be addressed at the beginning of the next session. According to [10], key preparation steps include setting an agenda, defining objectives and methods, assigning responsibilities, determining necessary participants, and sending the agenda along with the meeting invitation.
Conduct the Meeting	Construction meetings are typically moderated and documented by the host (e.g., construction managers on the construction site) or the project manager. At the beginning, the participant list is shared, the agenda is presented, and additional topics can be proposed if they fit the time frame and are relevant. Formal rules for communication and conduct are then established to ensure respectful and efficient discussions, after which agenda items are addressed, lessons from past projects are considered, and visualization tools like projectors may be used to support the meeting.
Post-processing	The follow-up to a construction meeting consists of thorough documentation. All discussed content, decisions, and agreed actions should be recorded accurately and concisely, without adding any incorrect or assumed information. Previously resolved items should be removed to maintain a clear and precise meeting record, and supporting materials such as drawings and photos should be attached to enhance understanding.

In addition to these phases, there are several other important aspects that need to be considered in construction meetings, such as project boundaries, the degree of regulation, the number of participants, the direction of information flow, and more. A major challenge for communication arises from the heterogeneity of participants in construction meetings, as not only construction contractors but also clients and associated parties (e.g., project managers, consultants, prospective buyers) are involved.

Furthermore, differences in experience (e.g., junior site manager vs. senior site manager) and technical expertise pose additional challenges in these meetings.

These factors also affect project communication. Communication can be differentiated in various ways, most notably between direct and mediated (i.e., technology-based) communication. Direct communication relies on sensory perception and does not require additional tools to convey information. In contrast, mediated communication depends on auxiliary tools to deliver content, using non-location-bound communication methods such as E-Mail, Video conference, Text messaging and so on (to be specified). By using immersive technologies, virtual meetings could combine virtual and real world elements, e.g. by using avatars [12] or real-time rendering, such as Gaussian Splatting to show the status quo on the construction site [13].

The share of hybrid construction meetings—in which only part of the team is physically present—has increased significantly, particularly due to COVID-19 [14]. As a result, in various industries, meetings often involve a hybrid mix of in-person, direct communication and the use of technical means, which leads to an increased efficiency [15]. The following section will therefore focus on mediated communication in the broader sense, particularly through immersive technologies.

2.2. Immersive Technologies and Application on Construction Sites

There is no universally accepted definition for the term immersive technologies [16]. For this reason, an exploratory literature review was conducted. The definition that the authors found most appropriate is that of Milgram & Kishino (1994):

“Immersive technologies enable experiences that blend digital and physical realities, ranging from augmented overlays to fully synthetic environments.” [17].

Currently, immersive technologies are primarily associated with the use of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR).

1. **Virtual Reality (VR):** Virtual Reality (VR) generates a fully digital and immersive environment that allows users to experience a virtual world through a VR headset. Users can move freely within the virtual environment and interact with objects. In the construction industry, VR is primarily used for building walkthroughs, simulations, and training purposes. [18]
2. **Augmented Reality (AR):** Augmented Reality (AR) enhances the real-world environment by overlaying additional digital information, which can be displayed via smartphones, tablets, or AR glasses. Users see the physical world enriched with 3D models, annotations, and more. In the construction industry, AR is often used to project construction processes in real time on-site and to carry out quality inspections. [19]
3. **Mixed Reality (MR):** Mixed Reality is a combination of VR and AR. It blends digital content with the real world, allowing both to interact with each other. Users can touch, move, and adjust virtual objects in real time, while the physical environment remains visible. In the construction industry, MR is used for collaborative planning, component placement, and digital twins, enabling the connection between physical and digital models. [20]

The difference between AR and VR is illustrated using a civil engineering-specific teaching module in the following Fig. 2 and Fig. 3.

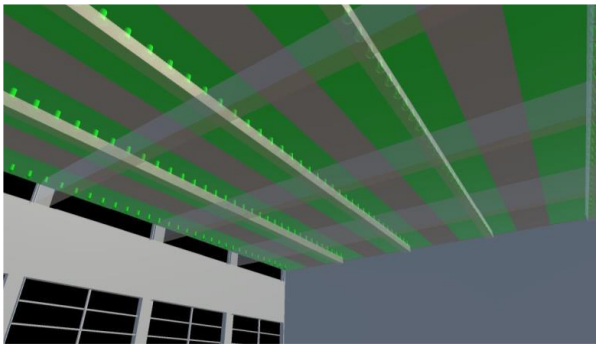

Fig. 2 Load transfer of a ceiling structure visualized in VR (real-world environment hidden), view facing the window. [Own Illustration]

Fig. 3 Load transfer of a ceiling structure visualized in AR (overlay of the physical space), view facing the interior wall. [Own Illustration]

Even now, there is a wide range of potential immersive technologies available for construction meetings, although many of them are manufacturer specific. For example, Microsoft offers immersive spaces within Teams. Meta headsets are frequently used, as the Meta Quest 3 supports both AR and VR modes. [21] In addition, there are haptic technologies that aim to simulate virtual touch and material sensations. Since these are still in earlier stages of development, they will not be further discussed in the following. However, in the future, the combination of haptic and immersive technologies could offer additional potential for construction execution.

3. Research Questions and Methodology

Based on the previous descriptions, several challenges emerge that are particularly relevant when applying immersive technologies during the construction phase. From these, two research questions are derived and will be addressed in the following:

1.) What challenges and opportuinites arise from the use of immersive technologies during the construction phase for the client (principal) and the contractor?

2.) What strategies can be developed to further advance the application of immersive technologies and mitigate the associated challenges?

To answer the research questions, both a deductive and an inductive approach are applied (see Fig. 4). The challenges are analysed through a deductive SWOT analysis. Subsequently, the results are validated inductively through interviews conducted as part of a scientific master's project. This combination allows for conclusions to be drawn regarding the application, development, and challenges of immersive construction meetings.

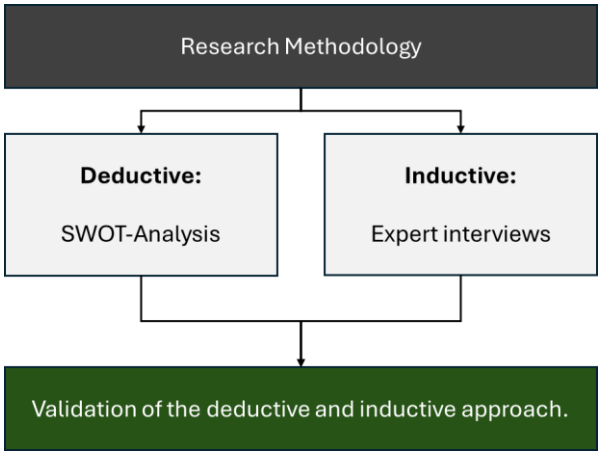

Fig. 4 Methodology to answer the questions [Own Illustration]

3.1. SWOT Analysis

The SWOT analysis is a method for evaluating the strengths, weaknesses, opportunities, and threats of a company, project, or technology. It was developed in the 1960s by the American business consultant Albert Humphrey [22]. The method helps to identify and analyze both internal and external factors in order to make informed decisions, particularly with regard to weighing up opportunities and risks for implementation [23].

The results are collected and analyzed using a four-field matrix. Based on these results, strategies can be derived to leverage strengths, minimize weaknesses, capitalize on opportunities, and mitigate threats. In this context, the construction execution phase is considered as a whole rather than focusing on a single company. Thus, the assessment focuses on the applicability of the technology for the entire industry. [24]

The SWOT analysis presented below is based on a qualitative literature review conducted for this paper. The foundation consists of various scientific articles (journal and conference papers) published between 2020 and 2025. In addition, the findings were validated against the practical experience of the authors.

3.2. Expert Interviews

Expert interviews are a qualitative research method used to gather opinions and in-depth knowledge from professionals on a specific topic. The primary goal is to identify challenges and positive aspects in order to draw conclusions that can help advance a method or research initiative [25].

The expert interviews were conducted using a structured interview guide. For this purpose, various scenarios typical of the construction phase (e.g., handling conflicts or changes) were developed and discussed with the experts during the interviews. The interviews were conducted between October 2024 and November 2024 and were recorded. A total of 11 experts were interviewed. The evaluation was carried out using category-based analysis according to Mayring [26].

4. Results

After outlining the fundamentals of the topic, the research questions, and the methodology, the following section presents both the SWOT analysis and the results of the expert interviews.

4.1. Finding of SWOT-Analysis

Construction meetings typically involve both the contractors (construction companies) and the clients (owners). As explained in Chapter 2.1, there is a high degree of heterogeneity among the participants. Due to the resulting divergent requirements of contractors and clients, two separate SWOT analyses are presented below. Table 2 focuses on the contractors, while Table 3 focuses on the clients.

The strengths shown in Table 4 arise for contractors primarily through improved visualization and decision-making processes, which represent a key success factor for construction projects and meetings. In addition, opportunities emerge from optimized workflows and enhanced collaboration in hybrid meetings, as connecting online participants to construction meetings currently poses significant challenges. These challenges are often due to the dynamic nature of the meetings, the lack of gestures, and limited spatial presence.

Weaknesses are mainly the result of high investment costs for hardware and software, as well as training requirements and limited user familiarity or change management processes. Risks exist particularly for individuals with little technical experience, as well as due to potential technical failures (e.g., poor internet connectivity, hardware malfunctions).

Table 2 SWOT with the focus on the contractor

Strengths	**Weaknesses**
• Improved visualization of complex construction projects • Faster decision-making through immersive meetings • Better error detection before execution • Increased efficiency and collaboration between teams	• High investment costs for hardware and software • Need for staff training • Technological barriers in on-site implementation • Lack of standardization and interoperability among systems
Opportunities	**Threats**
• Integration with Building Information Modeling (BIM) for optimized workflows • Cost savings through reduced misunderstandings and planning errors • Enhanced collaboration in hybrid meetings • Potential for future innovation and automation due to a growing market	• Acceptance issues among older or less tech-savvy employees • Data protection and security concerns related to project information • Technical failures or compatibility issues with existing systems • Dependence on stable network infrastructure on construction sites

The SWOT analysis for clients presented in Table 22 shows a similar picture to that in Table 3. In particular, more effective communication and increased transparency are seen as key strengths. Opportunities arise from more efficient monitoring and a reduction in the need for physical presence on construction sites.

Weaknesses are primarily associated with potential resistance to new technologies and the costs of implementation. Additionally, risks include the high time and financial investment required, as well as the possibility that the technology may ultimately fail to gain widespread adoption.

Table 3 SWOT with the focus on the client

Strengths	**Weaknesses**
• Better control over construction progress through immersive meetings • Greater transparency and traceability of planning decisions • More effective communication with all stakeholders • More precise quality assurance through real-time digital inspections	• Need to familiarize internal staff with the technology • Potential resistance to new digital processes • Costs for implementation and integration with existing workflows • Risk of uneven technology adoption among different project partners
Opportunities	**Threats**
• Ability to monitor construction projects more efficiently and detect errors early • Reduction of change orders and delays through clear visualizations • Improved sustainability through optimized material planning • Development of new digital standards for construction monitoring • Reduced need for physical presence on construction sites	• High time and cost requirements for initial implementation and testing phases • Data protection concerns, particularly regarding sensitive project information • Risk that the technology may not gain long-term acceptance • Dependence on technological developments and updates • Decreased acceptance of instructions from the client by other stakeholders

The SWOT analysis provides an indication of how immersive technologies may impact changes in construction meetings. In the following section, the results are compared with the findings from the expert interviews and discussed in Chapter 4.3.

4.2. Results from the Interviews

A total of eleven problem-centered expert interviews were conducted. The interviews were carried out by Yannik Will as part of a scientific research project. Among these, six were conducted with clients and four with contractors. The qualitative content analysis followed the approach of Philipp Mayring. His 13-pillar model of qualitative thinking was taken into account during the analysis process. For further information, see [27].

The results regarding the potentials and challenges of using immersive technologies were quantitatively grouped into six categories and visualized in the following bar chart (see Fig. 5). The bar chart presents a comparative evaluation on a scale from 1 to 10 in order to better illustrate the strengths and weaknesses of the technological approaches.

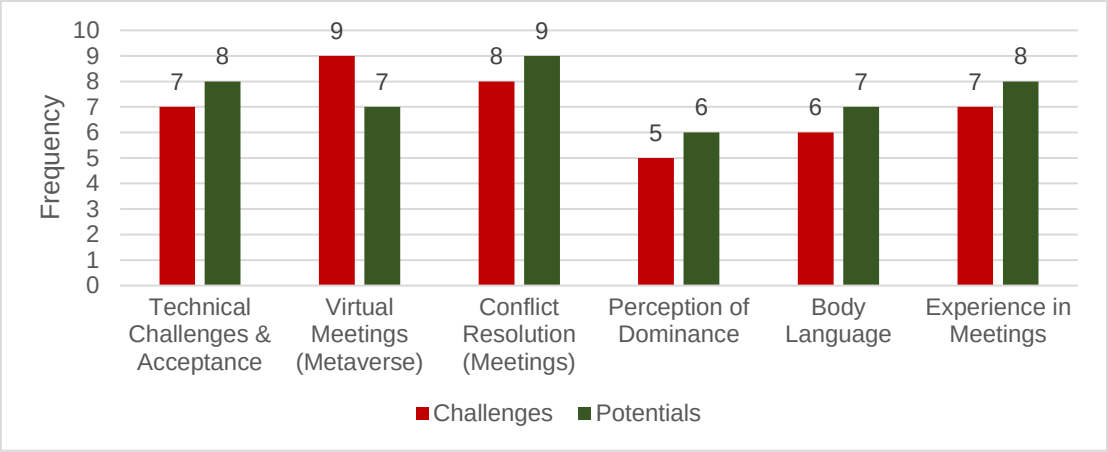

Fig. 5 Presentation of the Expert Interview Results Based on Frequency

The expert interviews showed six major findings:

1. **Experience in Meetings and Conflict Resolution:** Conflict management in construction meetings is highly dependent on the experience of the moderator. Moderators with strong analytical skills and conflict resolution strategies were seen as crucial for effective dispute resolution. Structural and organizational issues are often the root causes of conflicts rather than technical/material defects. Virtual meetings require more intensive discussions as deeper problems are less immediately visible
2. **Role of Moderators and Nonverbal Communication:** Moderators should remain neutral and adapt to the behaviors of participants to create a productive atmosphere. The ability to interpret nonverbal cues (body language, tone and facial expressions) plays a key role in resolving conflicts. Some experts warned about misinterpretation of body language, which could lead to biases.
3. **Use of Technology in Meetings:** There was a divergence in opinions regarding the necessity of advanced technology in conflict resolution:
    i. Some experts argued that simple communication tools like phone calls were sufficient.
    ii. Others emphasized that virtual meetings require structured preparation and additional technological support.

    VR meetings offer advantages in visualizing construction plans and saving travel time, but they lack emotional nuances and nonverbal cues.
4. **Challenges and Benefits of VR:** VR meetings improve focus and structure but struggle with the loss of body language and emotional expression. Emojis, chat systems, and alternative nonverbal communication tools were suggested as potential solutions, but their effectiveness is debated. Breakout sessions were recommended to facilitate smaller group discussions for conflict resolution.
5. **Acceptance of New Technologies:** Many experts noted resistance to VR adoption, particularly among older participants, due to discomfort with headsets. A gradual introduction of VR with proper training can improve acceptance. Enhancements like realistic avatars, improved ergonomics, and intuitive interfaces could boost usability.

The interviews showed, that immersive construction meetings in VR have the potential for conflict resolution but require structured moderation and clear communication strategies. Hybrid approaches (combining virtual and physical meetings) are considered the most effective. Technical improvements in VR tools, training, and adaptation strategies are necessary to increase user acceptance and effectiveness.

4.3. Discussion and Conclusions Drawn from the Results

Based on the expert interviews and the SWOT analyses, categories can be derived along with corresponding conclusions on how immersive meetings can be designed and successfully implemented. Table 44 presents a comparison of the results from the SWOT analysis and the expert interviews.

Table 4 Conclusions to implement immersive meetings in construction meetings

Category	Conclusions
Experience in Meetings	Immersive technologies improve information exchange but require trained moderators for conflict resolution.
Body Language	VR can reduce or distort body language, which may lead to misunderstandings.
Perception of Dominance	VR meetings can flatten hierarchical structures, promoting collaboration, but may also alter existing power dynamics..
Conflict Resolution in Meetings	Virtual meetings require clear structures to minimize misunderstandings but can optimize routine meetings.
Virtual Meetings (Metaverse)	Virtual meetings facilitate planning and save time, though emotional nuances may be lost.
Technical Challenges & Acceptance	Implementation requires high investment, but training and improved VR technology can help overcome adoption barriers.

It is evident that immersive technologies offer significant opportunities in the construction phase. However, they also present particular challenges, especially in terms of nonverbal communication, user acceptance, and the need for effective moderation.

One way to increase acceptance is through expanded training in immersive technologies, providing users with support in both application and understanding. In addition, professional change management is essential for successful implementation. It is also necessary to further standardize the technology in order to simplify its application and thereby foster broader acceptance. The findings presented here are exploratory in nature.

5. Answering the Research Questions and Outlook

Against the background of the addressed research questions, the two questions can be answered as follows:

1.) What challenges and opportunities arise from the use of immersive technologies during the construction phase for clients and contractors?

The challenges and opportunites were identified through the SWOT analyses presented in Table 22 and Table 33. Of course, these findings can be further expanded through a systematic literature review and additional workshops with a broader range of experts. A comparison of the initial results is summarized in Table 4, providing a first overview.

2.) What strategies can be developed to further advance the application of immersive technologies and mitigate the associated challenges?

The strategies can be derived from the identified challenges. While the strategies presented are not exhaustive, they highlight the most significant approaches based on the literature and expert interviews. A key barrier is often the lack of market acceptance. This can best be addressed through targeted training and the implementation of a structured change management process.

Immersive technologies offer a forward-looking opportunity to make on-site construction processes more efficient. However, these are preliminary findings that require further validation. To verify the assessments and results, additional interviews with a broader range of participants from the construction industry are necessary. Moreover, the structure of future interviews must be adjusted to further investigate the findings already obtained. This will require further quantification and validation.

In general, a positive perception of immersive technologies can be observed. However, these methods still need to be established among clients, for example, by being specified in tender documents or by being regarded as standard practice by contractors. For this to happen, the necessary personnel must be available and willing to actively engage with the topic. In particular, the use of immersive technologies on construction sites is essential in order to fully explore the potential, address the challenges, and take the next steps toward implementing immersive construction meetings.

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