collaboration between the office and worksite (Wang and Chen, 2020, Alsafouri and Ayer, 2019). Using BIM-based AR, site professionals can visualise and interact with full-scale 3D BIM, and collaborate with the office using the superimposed model. The majority of studies investigate general AR applications such as training, hazard recognition, and assembly guidance which do not depend on interacting with full-scale BIM models (Amin et al., 2023). This has diluted the focus needed on BIM-AR considering the fundamental differences between BIM-AR and general-purpose AR applications. Differences include the need for a meticulously designed software architecture to effectively transfer the large amount of information in design models to worksites using BIM-AR. In addition, advanced localisation techniques are needed to attain the precision and stability of superimposed models (Amin et al., 2023). Furthermore, the majority of BIM-AR research is more focused on the developer perspective than the practitioner perspective. Although a large number of studies have highlighted the technical and technological challenges of general AR applications, fewer studies have contextualised their findings in real-world examples or explored insights from practitioners (Nassereddine et al., 2022a, Amin et al., 2023). Many scholars have argued the need to align the tools of BIM-AR with the specific requirements of existing practices in the construction industry (Davila Delgado et al., 2020a, Xu and Moreu, 2021). To that end, this article identifies use cases for BIM-AR through the lens of a practitioner and proposes changes to existing BIM workflow to leverage BIM-AR in light of the identified use cases.

BIM requires business transformation with regard to mindset, process, and platform (Amin and Abanda, 2019). BIM-AR is much the same, requiring closer academia and industry collaboration to advance the technology. In this article, we reflect on personal experience and observations of implementing BIM-AR in real project settings in the pre-construction and construction stages. A modified BIM workflow that incorporates the use of AR in its phases is proposed. First, through a literature review, we survey the use cases of AR identified in prior studies and extract the use cases that can be relevant to BIM in the context of onsite installation and validation activities of MEP services. Second, existing BIM workflow is described to highlight the bottlenecks in information flow between the office and the site. Finally, a new workflow for BIM-AR is proposed in the context of the identified use cases. At this point, we investigate how the use of BIM-

Table 1 Summary of the most relevant studies that have surveyed AR use cases in the built environment

Article	Stage	Technology	BIM-AR focused?	Conclusion of Research
(Schiavi et al., 2022)	Design to Operation	AR/VR	No	Identified two categories for AR and VR use cases: activities and training
(Nassereddine et al., 2022a)	Pre-Construction to Operation	AR	No	Identified 42 use cases

3. Reflecting on existing BIM workflow

The existing BIM workflow can be divided into three phases. The first phase includes conducting 3D model-based cross-trade coordination through consequent quality gates. This process involves several cycles of clash detection and model renditions between project participants. Despite the availability of many robust BIM collaboration tools, the design coordination process seldom results in a constructible model with the desired quality. This can be attributed to factors like conducting design coordination in silos, last-minute changes, and focusing on producing a clash-free model overlooking aspects related to constructability, maintainability, and operability. The resulting model is then used to produce 2D drawings that reflect the coordinated design. In most cases, reviewing 2D drawings may require model-based changes and require more revision cycles. The practice of using printed drawings for information exchange has been the norm for decades and will probably be used for years to come. This form of media is more accessible and can be easily shared between stakeholders. However, generating 2D drawings from 3D models is a challenging, resource-in

4.1 Pre-installation augmented design

In pre-installation use cases, BIM-AR is an additional quality gate that takes place onsite to further validate design information before starting installation. The objective of BIM-AR then is to visualise full-scale

Figure 5 providing real-time feedback on design before and during installation.
Image courtesy of XYZ Reality Limited (XYZ Reality, 2022)

The integration with cloud-based document management systems has enabled generating and retrieving different forms of feedback that are linked to locations or elements in the design model. And so, through closer design-construction integration the speed of learning is real-time, and the digital audit trail is clearer.

4.2 Post-installation

The objective of post-installation use cases is to timely capture installed items in an accessible form that can be easily used to develop as

Overall, the early detection of errors and risk mitigation prior to starting installation can minimise rework and lead to cost

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May 27, 2023

Subject: Revision and resubmission of manuscript Submission 6541

Dear Conference Committee,

I am writing to submit a revised version of my conference paper titled "Augmenting [illegible]" for consideration for the upcoming 30th International Workshop on Intelligent Computing in Engineering. We appreciate the opportunity to revise and resubmit the paper based on the valuable feedback received from the reviewers. We have carefully addressed the reviewers' comments and suggestions either by modifying the manuscript or responding to the comments in this document. We value the insights and expertise of the conference committee and the reviewers, and we are confident that the revision has improved the contribution and originality of the research.

Sincerely,

Khalid Amin

The Bartlett School of Sustainable Construction

Comments from Reviewer 1

Comments from Reviewer 2: