COMPARISON OF CURRENT COMMON DATA ENVIRONMENT TOOLS IN THE CONSTRUCTION INDUSTRY

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Abstract

The basic premise of a Common Data Environment (CDE) proposed by ISO19650 is exposing all relevant data as a single source of truth for all stakeholders. This work investigates tools currently used as CDE solutions in the industry and their practical challenges. Data was collected through a web search, a survey, and semi-structured interviews with industry professionals. Twelve tools were identified and compared in a desk review providing insights into their strengths and weaknesses. The results show that multiple CDEs are needed throughout the project lifecycle as no tool on the market can provide required functionalities in all lifecycle phases.

Introduction

A Common Data Environment (CDE) is the foundation of information management processes in BIM-based collaboration (BSI, 2021). The concept of a Common Data Environment first appeared in BS1192:2007 and was further expanded in PAS 1192-2:2013. A new international standard, ISO 19650, was released in 2019 for the CDE-based information management workflow (AEChub, 2022).

Since the publication of ISO 19650, a multitude of software tools that can be used as a CDE with varying levels of ISO standard conformance has been developed. The UK National BIM survey 2020 (NBS, 2020) listed several tools used as a CDE by industry practitioners, including Viewpoint/4Projects (used by almost 50% of the respondents), Autodesk BIM 360 (39% usage rate), and Aconex/Conject (36% usage rate). Furthermore, 38% of respondents use Microsoft SharePoint and another 36% use Dropbox, both general-purpose file-based document management systems, in place of utilising a CDE specifically designed for that purpose (NBS, 2020).

While there are plenty of CDE options, each feature wide and varied functionalities and require quite distinct implementation pathways. This diversity is not always conducive to facilitate collaboration and traceability in information management. There is a lack of common understanding of what a CDE tool is and what functionalities it should provide in each lifecycle phase. A research study by Kiu *et al.* (2022) explores the characteristics of a few common Electronic Document Management Systems (EDMS) tools in design and construction. The BIM study (NBS, 2020) revealed the tools that practitioners use throughout the design stage, but it did not give any more details on the experiences of users using CDE tools. It is unclear how the tools are utilized or whether they meet the demands and requirements of the users or the ISO19650 standard. This work fills this gap by investigating tools currently used as CDE software in the industry and their practical challenges. The main research question of this study is: What tools are currently used in the AECO industry as a CDE, and what are their core functionalities? Answering this question will lead to a better understanding of current CDE development and can be a starting point to improve the CDEs functionality leading to a more efficient BIM-based information management workflow.

Literature review

Construction projects typically involve a wide range of stakeholders who communicate throughout several phases of the project lifecycle. Unavoidably this process generates a massive amount of data and therefore good management of information is crucial for every construction company (Kiu *et al.*, 2022). A CDE's aim is to provide all relevant data in a single source of truth, facilitating seamless information sharing, and fostering continuous collaboration between all parties involved. (Hijazi *et al.*, 2021). According to ISO 19650, entire information exchange in construction projects should be facilitated by a CDE for sharing and coordinating information, using open standards whenever possible, and clearly defining operating procedures to enable a consistent information exchange for all organisations involved in a project. CDE is defined in the standard as *"an agreed source of information for any given project or asset for collecting, managing, and disseminating each information container through a managed process"*(BSI, 2021). A CDE could mean both a "CDE solution" or a "CDE workflow". The "CDE solution" is a server-based or cloud-based repository that supports the CDE process

by providing database administration, transmittal, problem tracking, and similar features. A CDE Workflow organises the flow and management of information over an asset's entire life cycle through the use of four Information Container States (BIM Dictionary, 2020). ISO 19650 (BSI, 2021) describes four states in which each information container can be: work in progress (WIP), shared, published, or archived; the transition from one state to another should be subject to approval and authorisation processes (BSI, 2021).

To provide a more comprehensive definition of what CDE is, Bedoiseau *et al.* (2022) developed a 4-level classification of CDE features including areas such as documents, coordination, communication and BIM Production. In their study, Level 0 represents a pre-CDE without any digital solution. Level 1 corresponds to Electronic Document Management (EDM) systems which satisfy basic ISO 19650 requirements but do not enable BIM editing directly in the tool. Level 2 is referred to as an "advanced level" since it offers additional functionalities such as a version-control system for review and approval workflows, BIM visualisation and editing, multidisciplinary coordination and clash detection. Level 3 CDEs should be centred around a single multidisciplinary BIM model enabling the creation and editing of models and synchronous communication within CDE (Bedoiseau *et al.*, 2022).

Das *et al.* (2021) classified data-sharing platforms into three BIM security levels, covering data, network, and system security, as well as data ownership, sharing,

unstructured servers. Level 3 includes structured-data servers like Autodesk 360, offering easy storage and transmission of BIM data and high data granularity. (Das *et al.*, 2021).

Based on the studies by Das *et al.* (2021) and Bedoiseau *et al.* (2022) we proposed a comprehensive framework to evaluate the development of CDE platforms, as shown in Figure 1 (Jaskula *et al.*, 2022). Previous works did not take into account the lifespan of data in construction projects. The information lifecycle in construction projects can be separated into two stages: information delivery and information operation. The former covers data from the project's initiation through its design and construction phases, resulting in the creation of PIMs (project information models). The latter encompasses data from the operation and maintenance (O&M) phase of the built asset, leading to the production of AIMs (asset information models) (BSI, 2021). In the framework, features listed by Bedoiseau *et al.* (2022) such as documents, coordination, and communication, have been combined into a single axis related to document management. BIM integration is a distinct aspect of CDEs that is separate from document management functionalities and is therefore identified as the second axis. Security, as highlighted by Das *et al.* (2021), has been included in the framework as the third axis of CDE development. The final axis pertains to the lifecycle functionalities that allow the use of CDE in various lifecycle phases of a built asset.

Research method

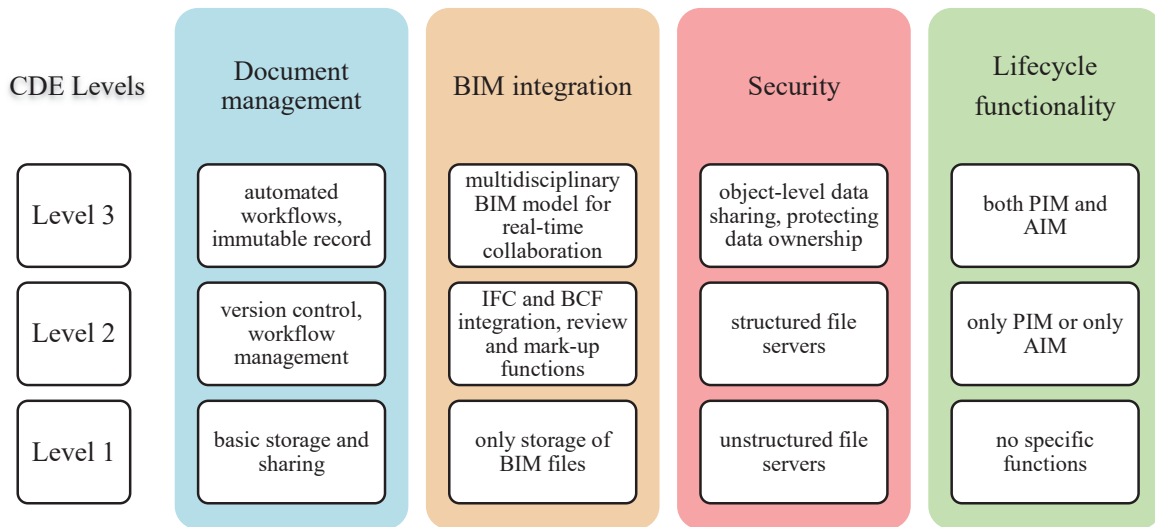| CDE Levels	Document management	BIM integration	Security	Lifecycle functionality
Level 3	automated workflows, immutable record	multidisciplinary BIM model for real-time collaboration	object-level data sharing, protecting data ownership	both PIM and AIM
Level 2	version control, workflow management	IFC and BCF integration, review and mark-up functions	structured file servers	only PIM or only AIM
Level 1	basic storage and sharing	only storage of BIM files	unstructured file servers	no specific functions

Figure 1: Framework for CDE maturity assessment (Jaskula et al., 2022)..

integrity, and information flow. The first level includes unstructured file servers, such as Dropbox and Samba file servers, commonly used by small and medium-sized construction businesses due to their low cost and easy deployment. However, these file servers lack the necessary functionality and security, resulting in a single point of failure and compromised data privacy. Level 2 consists of structured file servers that maintain relationships between files, providing better security than

This research study is combining desk research with qualitative methods such as a survey and semi-structured interviews with industry professionals. A desk review of the most common CDE software available in the market was conducted through a web search.

The aim of the survey and the interviews was to understand the present level of CDEs adoption and the challenges associated with utilising them in reality. The

poll was open to all construction industry professionals, regardless of their BIM experience to gain a general overview of the industry's current state. The survey's URL was shared on social media and sent to contacts in the researchers' professional network. No personal information was gathered for the study, which was entirely anonymous. It required an average of 10 minutes to complete.

The survey attracted 41 respondents, including professionals from different disciplines and construction project stages. Most participants were BIM managers (18), followed by architects (11) and project managers (10). Most participants were from northern European countries, such as the UK (11) and Ireland (8) For the semi-structured interviews, only experts in BIM adoption were sought, as they have the best knowledge about the practical implementation of CDE tools in practice. The target interviewees were project managers, BIM managers, general contractors, and facility managers, as insights about information management in all phases of assets' lifecycles were searched for. Individuals from the researchers' professional network were identified and asked for participating in the interview. The interviewees were first asked to describe the BIM adoption level and how they deal with information management in their projects. Further, they were asked to elaborate on

information management challenges they experienced while using CDE tools.

In total, fifteen participants were interviewed from different companies, positions and years of experience, as seen in Table 1. The interviewees have been chosen based on their tendency to participate, experience, background in AECO, and experience with BIM-based project management. The interviews took place between November 2021 and April 2022. Each interview took between 40 and 80 minutes, and the recordings were transcribed and verified.

Through the use of coding, a researcher can identify themes or patterns in their qualitative data that can be further investigated in relation to their research topic (Saunders *et al.*, 2019). To analyse the results of the interviews a thematic analysis via coding was carried out on the interviewee transcripts (Braun and Clarke, 2006. The transcripts of the interviews were imported to NVivo 2020, and code-related text excerpts related to each of the tools were highlighted by the researcher to recognise the frequency of their emergence throughout the transcripts. This study is based on an inductive approach as data collection is used to identify themes and patterns (Saunders *et al.*, 2019). The outcomes were summarised in a comparison table and a descriptive manner.

Table 1: Semi-structured interviews' participants' list.

No	Position	Expertise	Years	Country	BIM expertise	Used CDE tools
1	Consultant	Standards, regulations, BIM implementation	20+	UK	expert	
2	BIM Manager/ researcher	Project management, research	15+	UK	expert	BIM 360, Aconex, Sharepoint
3	BIM Manager	Project management, architectural practice	5+	UK	expert	BIM 360, Aconex
4	Consultant	MEP, HVAC planning	15+	Sweden	very good	
5	Blockchain developer, researcher	Blockchain applications development	<5	UK	not applicable	
6	Consultant/ researcher	Implementation of IT in construction	30+	Denmark	very good	
7	Consultant	Smart buildings, sustainable construction, General Contractor	30+	Sweden	very good	
8	BIM Manager	Project management, General Contractor	20+	Ireland	expert	Autodesk Glue, Viewpoint
9	Construction manager	Digital management, design management	10+	Ireland	expert	BIM 360, Autodesk Glue, Viewpoint
10	Consultant/ researcher	Implementation of IT in construction	20+	Sweden, Denmark	very good	
11	BIM Manager	Project management, architectural practice	5+	UK	expert	BIM 360, Aconex
12	Consultant/ researcher	Asset management from the owner side for infrastructure projects	10+	Estonia	very good	
13	Facility Manager	Facility management of public assets	5+	Ireland	expert	Autodesk Glue, Cylon
14	Department manager	Digital construction in project management, General Contractor	15+	Sweden	expert	

15	Development director	Facility management	20+	UK	expert	BIM 360 Ops, Concept Evolution CAFM

Findings and results

In the desk review, we compared the most popular software solutions used as a CDE during the project delivery stage. The selection of the tools was based on the results of the NBS BIM Report 2020 (NBS, 2020) and the survey and interview results. Additionally, we conducted a web search to find more information about the selected software. Reviews of each software from the online comparison platform Capterra (2022) were analysed and combined with the statements of the interviewees using these tools. Based on that we analysed the maturity of each platform according to the assessment framework presented in Figure 1. Additionally, we compared the usage rate from the BIM survey 2020 (NBS, 2020), price per user and month for each platform and Capterra user rating. The results of the comparison are presented in the following Table 2.

To investigate what tools are used in the industry to store and exchange information in construction projects we conducted an online survey with industry stakeholders. Participants were asked, "What per cent of project data is managed and exchanged through the following methods?" and a list of different tools was provided. The results in Figure 2 show that more than half of the survey participants use emails for information exchange in all projects. Cloud-based repositories, such as Dropbox, OneDrive or Google Drive, are widely adopted for exchanging project information, as 20 participants use it for more than 60% of project information. CDE solutions for BIM coordination, such as BIM 360, were mentioned as the main source of information by 9 participants. At the same time, 15 participants use CDEs for document management such as Viewpoint4Projects or Aconex to manage at least 40% of the information. BIM Collaboration Format (BCF) is apparently still in a very low adoption rate, as only 2 participants use it in all of their projects and 19 do not use it at all. Private servers were the least used tools to store data, followed by the CMMS, however, a low number of facility managers taking part in the survey is responsible for the low percentage of usage of the latter system.

In the next question, the participants were asked to name the CDE solutions they use. Figure 3 presents the percentual use of different CDE solutions among survey participants. CDE from Autodesk namely BIM 360 was the most frequently used solution (almost 35% of participants). Cloud-based repository Dropbox was also a frequent answer (used by almost 10% of participants). Other popular solutions are Aconex (by Oracle), and Microsoft SharePoint.

BIM 360 from Autodesk was one of the most commonly used platforms according to both interview and survey results, as well as suggested by BIM Survey 2020. As Autodesk is the producer of most commonly used BIM software such as Revit or Navisworks, BIM 360 offers a direct synchronisation of BIM models created in those tools allowing a real-time collaboration in a shared BIM model, including automatic clash detection and providing constructability analysis (Autodesk, 2022). Moreover, it supports the management of Request of Information (RFIs) and submittals (Autodesk, 2022) typical for design and construction phases and, therefore can be classified as Level 2 for lifecycle functionality. It is much easier to issue RFIs with BIM 360 than with the Viewpoint platform (Interviewee 9). However, Interviewee 3 reported that BIM 360 does not include suitability codes, and one must manually type them into the system, which is time-consuming. It is one of the reasons interviewee 3 uses the Aconex platform instead, as it provides more reliability and enables tracking of all revisions made to each file. Interviewee 11 reported that BIM360 is a good coordination and design management tool but does not function as a CDE tool at such a level as other tools. Tools like Viewpoint4Project (Interviewees 8 and 9) or Aconex (Interview 11) are preferred for managing submittals, document revisions and sign-offs.

Aconex is a CDE solution proposed by Oracle which provides immutability of the files, advanced version control and a unique data ownership model (Oracle, 2022). Interviewee 3 stated that a big advantage of Aconex is providing a classification of suitability status and revision control, enabling easy information tracking. Although regular users are not allowed to change the information once it is saved on Aconex, the document manager is still able to do this, as reported by Interviewee 3. Therefore, all project participants must trust that the document controller will not manipulate the data, which is one of the system's weaknesses (Interviewee 3). Another limitation of Aconex is its lack of interoperability with other systems, including other CDEs and CAFM systems in later stages, which forces companies to use special software to hand over information between the systems (Interviewee 3). Moreover, Interviewee 2 argued that Aconex is a very expensive product and difficult to use. As Aconex provides a Uniclass naming convention, it isn't easy to find the required information without knowing the file's name (Interviewee 2).
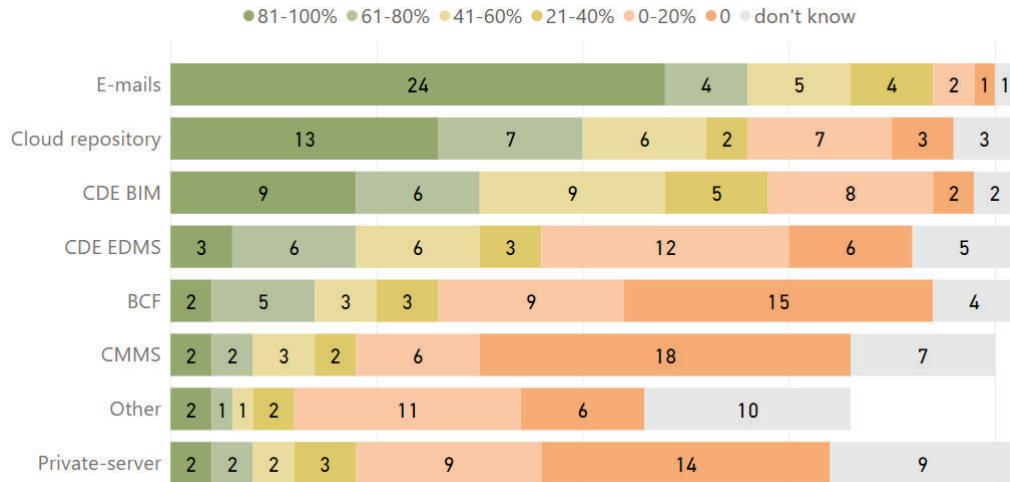
	81-100%	61-80%	41-60%	21-40%	0-20%	0	don't know
E-mails	24	4	5	4	2	1	1
Cloud repository	13	7	6	2	7	3	3
CDE BIM	9	6	9	5	8	2	2
CDE EDMS	3	6	6	3	12	6	5
BCF	2	5	3	3	9	15	4
CMMS	2	2	3	2	6	18	7
Other	2	1	1	2	11	6	10
Private-server	2	2	2	3	9	14	9

Figure 2: Use of sources of information in construction projects according to survey participants.

Viewpoint4Projects is a tool from Trimble enabling document management, risk management and BIM management functionalities (Trimble, 2022). It was the most used CDE, according to the BIM Survey 2020. Interviewees 8 and 9 reported that they are using Viewpoint as a document management software complementary to BIM 360, which is better for BIM coordination. Although Viewpoint is a basic and quite outdated tool, it is still better for revision and sign-offs of documents than BIM 360 (Interviewee 9). All submittals, documents and drawings can be stored on this platform which is used to share information with subcontractors (Interviewee 8). Viewpoint allows to set up of folders with different access levels so that only the main contractor has complete control to edit or delete uploaded data (Interviewee 9).

ProjectWise is a tool developed by Bentley that is closely integrated with Microsoft 365 products (Bentley, 2022). It provides advanced document management functions, like automation of submittal processes or design revision, while enabling easy access to all data through a web browser (Bentley, 2022). As none of the interviewees had experience with this particular tool, we looked for user reviews on the Capterra comparison portal (Capterra, 2022). The reviewers were happy with the document management functions of ProjectWise, especially the ease of sharing data in all formats and auditing file versions. However, they noted that learning requires much effort and may become slow when data has to be downloaded or uploaded into the system (Capterra, 2022).

Other less utilised CDE tools such as Deltek and Procore offer document management and BIM functionalities similar to Viewpoint, Asite or ProjectWise. Deltek offers modules for managing drawings, emails, contracts and tendering (Deltek, 2022). However, users mentioned that it is incompatible with all file formats and is still quite unstable (Capterra, 2022). Procore is a well-established construction management platform that simplifies work processes from tendering to handover (Procore, 2023).

Given the effort and complexity of CDE implementation, very often stakeholders utilise simpler tools which are already integrated with existing working practices such as cloud-based file repositories, including Dropbox, Google Drive or Microsoft SharePoint. For instance, Dropbox is a well-established data-sharing platform with simple organisation and basic document tracking and backup functionalities (Capterra, 2022). BIM survey 2020 reported that up to 38% of participants use Dropbox, and 36% use SharePoint as a CDE solution (NBS, 2020). Although those repositories lack the security levels required by ISO19650, object-level access control and interoperability with BIM software (Das et al., 2021), they are still widely adopted in the construction industry to easily share data among stakeholders.

The system and tools used to manage information in the O&M phase, such as CAFM and CMMS systems, were not included in the comparison due to the lack of
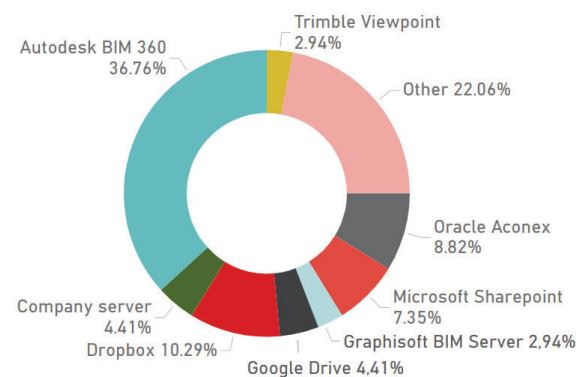
Figure 3: Percentual use of different CDE software among survey participants.

Autodesk BIM 360 36.76%
Trimble Viewpoint 2.94%
Other 22.06%
Oracle Aconex 8.82%
Microsoft Sharepoint 7.35%
Graphisoft BIM Server 2.94%
Google Drive 4,41%
Dropbox 10.29%
Company server 4.41%

sufficient information about their levels of adoption. The Interviewees working in this domain stated that, similarly to previous phases, there are multiple sources of information used simultaneously and that they are

completely different tools than those used in the design and construction phases. The CDEs included in the comparison are not suitable for managing the data in the O&M phase, as asset management data has different characteristics and requirements. Interviewee 13 mentioned a BMS software called Cylon, and Interviewee 15 a CAFM software called Concept Evolution. Interviewee 15 also mentioned that their company tested the CAFM tool developed recently by Autodesk called BIM 360 Ops. According to them, the tool does not meet their needs and is insufficient to manage building operation data at a similar level to other more established CAFM tools.

Another set of tools can be used to facilitate the handover of information between design and construction CDEs and FM systems. Interviewees mentioned using Springboard, gliderBIM and Autodesk BIM 360 Glue as tools for gathering and managing handover data. Springboard is a tool from eDocuments that provides an online database for gathering all data for handover in one centralised and easily accessible location (eDocuments, 2022). Additionally, Springboard provides O&M templates that help to automate the validation process and export tools for PDF, COBie, IFC or Asset Registers that enable direct integration with CAFM systems (eDocuments, 2022). However, gathering data through Springboard is still mostly manual, as CDEs like Aconex do not integrate well with Springboard (Interviewee 3). A recently developed tool called gliderBIM is advertised as a CDE solution for information management along the entire lifecycle of a built asset, including the asset management phase (Glider, 2022). Moreover, gliderBIM enables the export and import of IFC and COBie and integrates via API with CAFM, EDMS and BMS systems (Glider, 2022). As it is a very recent tool on the market, there are no reports from the users about its practical implementation, except for Interviewee 3, who reported that their company is implementing the tool in one of their projects. However, they plan to use gliderBIM as CDE only for published information owned by the client, while using Aconex for design coordination in parallel. A tool from Autodesk called BIM 360 Glue allows to establish a direct link between the BIM 360 used in the design and construction and the BIM 360 Ops used in the O&M phase. Interview 13 and Interview 9 reported that BIM 360 Glue allows to reduce the time needed to hand over all the required information to a matter of hours or even minutes. However, Interviewee 9 also reported that some of the clients do not even have a proper CAFM system for asset management and it happens that handover information is gathered manually in a SharePoint repository.

Table 2: Comparison of CDE platforms assessing their level of maturity (Bedoiseau et al., 2022; Das et al., 2021; Jaskula et al., 2022).

Name of the tool	User/month price	BIM survey users	Capterra rating	Document management	BIM integration	Security	Lifecycle Functionality
Autodesk BIM360 / ACC	£48 to £155	39%	4.3	Level 2	Level 3	Level 3	Level 2
Viewpoint 4projects (Trimble)	£15 to £50	50%	4.1	Level 3	Level 2	Level 3	Level 2
Aconex (Oracle)	£53 to £87	36%	4.4	Level 3	Level 2	Level 3	Level 2
Asite	From £375 per project	32%	3.6	Level 3	Level 2	Level 3	Level 2
ProjectWise (Bentley)	£49 to £145	18%	4.4	Level 3	Level 2	Level 3	Level 2
Deltek/ UnionSquare	n.a.	11%	2.8	Level 3	Level 2	Level 3	Level 2
Procore	From $375 (unlimited users)	5%	4.5	Level 3	Level 2	Level 3	Level 2
BIMcollab	£5 to £14	n.a.	4.3	Level 2	Level 3	Level 3	Level 2
Dropbox	£14 to £40	38%	4.5	Level 1	Level 1	Level 1	Level 1
SharePoint (Microsoft)	£4.10 to £22	36%	4.3	Level 1	Level 1	Level 1	Level 1
Google Drive	from £5	23%	4.8	Level 1	Level 1	Level 1	Level 1
One Drive (Microsoft)	£8.20 to £36	30%	4.5	Level 1	Level 1	Level 1	Level 1

Discussion

The comparison of various CDE platforms currently used in the industry provided insights into their strengths and limitations. Even though the current CDE solutions are very advanced, they are still not used as a single source of truth for the entire lifecycle of a built asset. Stakeholders reported that no platform could provide the required functionalities typical for each of the lifecycle phases in a single tool. The CDEs used in the design and construction differ significantly from the tools used in the O&M phase as they are used for different purposes. Moreover, even during one lifecycle phase, there are various tools used simultaneously by different stakeholders, as they also have different requirements and preferences. One of the most significant challenges is the lack of interoperability between the tools, as they are provided by different vendors. The tools are not integrated with each other and transferring data between them is often manual. Especially the handover of information between the construction CDEs and facility management platforms is very challenging due to the lack of interoperability.

Even though some of the relatively basic cloud storage solutions, such as Dropbox or SharePoint, are frequently utilized in AECO in place of a CDE, they cannot be regarded as a complete CDE solution. As indicated in the research by Das *et al.* (2021), they lack the necessary functionality and security required for BIM-based collaboration, such as object-level versioning and access control, or integration of federated BIM models. However, these tools are especially popular among SMEs as they are easy to use and their cost is relatively low compared to a full CDE solution (Das *et al.*, 2021). Small projects are less complex than large-scale projects and therefore a simple repository might be sufficient to manage all information.

Although more sophisticated systems like BIM 360 or Aconex are partially at Level 3 CDE, they still do not provide Level 3 in all four areas. Tools such as BIM360, Aconex, Viewpoint, Asite, ProjectWise and Deltek can be classified as Level 3 CDE according to the security aspect, as they provide a structured data repository. All these tools provide good integration with BIM at least at Level 2 as visualisation of issues in BIM models, and integration of collaboration formats such as BCF and IFC is provided. However, tools such as Aconex and Viewpoint focus more on document management functionalities, such as version tracking and automation of sign-offs and approvals and are especially useful for large-scale projects. However, they do not enable BIM editing in the software. Stakeholders in the design phase mostly use solutions like Autodesk BIM 360 or BIMcollab for BIM coordination as they integrate with BIM modelling tools to the highest degree and enable real-time BIM coordination. These tools can be rated as Level 3 CDE in the areas of BIM integration. Despite their advantages, collaborative BIM systems such as Autodesk BIM 360 rely on cloud service providers that do not meet BIM

security standards, including safe data divisibility and object-level data ownership (Das *et al.*, 2021).

A full Level 3 CDE in all four areas, as described in Figure 1, is currently unavailable on the market. Although most of the identified tools are advertised as CDE compliant with the ISO 19650 standard, none of them is used as a single source of truth along the whole lifecycle of a built asset or even during a single phase. The requirements of a CDE are different in each of the lifecycle phases, and there is no single tool that can cover all of them at once. There is no single tool on the market that might be used as a CDE along the whole building lifecycle. Moreover, developing such a tool in the future is probably impossible, as it is too complex for any software manufacturer. Some software vendors are developing a series of tools for each of the lifecycle phases, which are well-integrated and allow them to hand over data from one tool to another much more quickly and efficiently. However, this requires the stakeholders from each lifecycle phase to purchase the software from the same suite of products, which is usually not feasible in practice.

Conclusions

Due to the complexity of construction projects and the amount of data generated during their lifetime, efficient information management is crucial to ensure the success of a project. In BIM-based project delivery, a CDE solution is a base of information management as defined by the ISO19650 standard. This study aimed to provide a comprehensive analysis of tools currently used as a CDE and investigate how they are used in practice. Recognising the shortcomings and advantages of existing CDE tools can be the first step in developing new solutions to improve information management practices based on cutting-edge technologies.

According to the framework from Jaskula *et al.* (2022) there are three different levels of CDE maturity depending on four aspects: document management, BIM integration, security and lifecycle functionality. Widely adopted cloud repositories such as Dropbox can be classified only as Level 1 CDE, as they do not integrate well with BIM technology and do not provide more advanced document management functionalities and a high level of security. Advanced CDE tools such as Viewpoint, Asite, Procore, Deltek or ProjectWise can be classified as Level 2 CDE for BIM, as apart from document management functionalities, they enable BIM visualisation and communication based on BIM formats such as BCF and IFC. BIM 360 from Autodesk or BIMcollab platform provide a Level 3 BIM integration as design companies use them for multi-disciplinary real-time BIM collaboration. However, they do not provide Level 3 document management functionality such as Aconex or Viewpoint. This leads to the conclusion that multiple tools are needed in construction projects as they are used by multiple users having different requirements towards them. Furthermore, most of the current tools do not

integrate well with each other and cannot be used as a single source of truth for the whole lifecycle of a built asset.

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