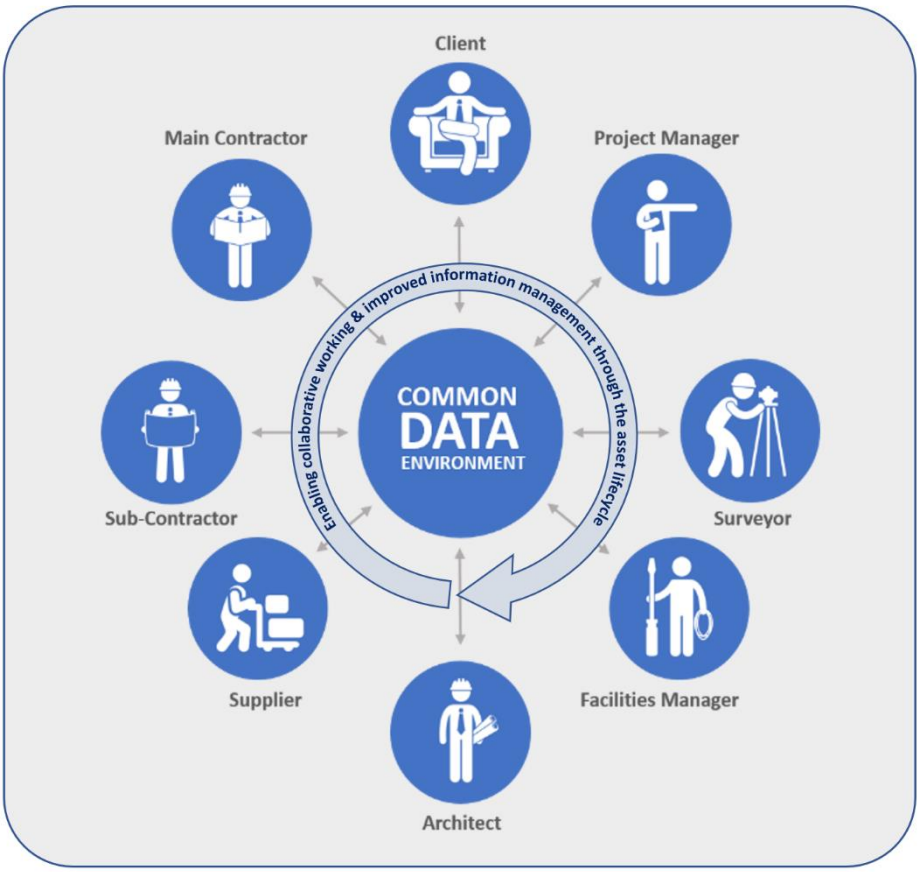
Implementation of a Common Data Environment

The Benefits, Challenges & Considerations

August 2018



SCOTTISH FUTURES TRUST

i3™ byAECOM

Acknowledgement

Prepared for:

The BIM Delivery Group for Scotland,
Scottish Future Trust (SFT),
bimdeliverygroup@scottishfuturestrust.org.uk

Prepared by:

Stefan Mordue
AECOM UK Limited
1 Tanfield
Edinburgh
EH3 5DA
UK
T: +44 7823 354 924
aecom.com

This document was developed in partnership with various consultees who provided their time to contribute to the research. A special thanks to Highland Council who contributed to the research and shared the lessons in how they procured an organisational common data environment.

Executive Summary

The Building Information Modelling Delivery Group (BIM DG) supports the Scottish Government in its objectives for a move towards a digital built environment and implement BIM as business as usual. To help achieve this, the BIM DG commissioned i3 by AECOM to undertake research in the implementation of common data environments (CDE). The British Standards Institute (BSI) defines the CDE as '***a single source of information for any given project or asset, used to collect, manage and disseminate all relevant approved files, documents and data for multidisciplinary teams in a managed process***'**.**

A CDE provides a platform upon which information in relation to our infrastructure is managed. Better information management will improve the decisions we make in how we plan, deliver and operate our public sector buildings which will ultimately improve the effectiveness and efficiency of the services they deliver.

This research seeks to outline the key benefits and challenges to implementation of a CDE. The research also assesses the capabilities and features of available CDE's 'on the market' and considerations that should be made when procuring a system. The key findings are summarised below:-

Need for CDE's

- A CDE is a fundamental part to deliver Scottish Governments BIM policy.
- A CDE will improve efficiencies through the whole asset life cycle.
- Good information management and collaborative systems will save time and money.
- Improve ability of organisations to respond in the event of building failure through accurate building records.
- Enable a robust information management system which is a foundation to future working practice and infrastructure technology.

Challenges to Implementation

- Complex IT procurement challenges. (Clear brief/compliance to existing IT procedures)
- Varied CDE market offerings.
- Cost and resources to procure a system.
- Maintain security of data.
- Developing a system solution compatible to existing organisational systems.

Benefits of a CDE

During Design & Construction Stage

- Greater reliability of data and reduced risk.
- Support more efficient processes in the creation and management of information.
- Reducing the time and effort required to check, version and reissue information.
- Reducing the time and cost of producing coordinated information.
- Enable to improve collaboration and improved outcomes.

During Operational Stage

- Save time to transfer accurate and complete information from construction to operational stages.
- Easy access to relevant and reliable information in the event of failure.
- Enable improved estate planning, procurement and maintenance.
- Support improved analysis across portfolio of built assets.

The opportunity exists to support procuring authorities implement CDE within organisations. This will bring transformational change to project delivery, maintenance and set the foundation to adopt new digital ways of working into the future. This research provides an overview of the principles, market offerings, considerations and challenges when implementing a common data environment.

Table of Content

1 Overview of a CDE and its importance in BIM adoption

We are currently in the midst of a perfect storm with a number of drivers coming together to improve data management and collaborative ways of working, centred around a national momentum, reports, government policy and advances in technology. Table 1-1 highlights key drivers that have pushed the adoption of a CDE.

Table 1-1 Key drivers for CDE adoption

Driver	Description
Industry reports	Latham, Constructing the team (1994), Eagan, Rethinking construction (1998) and Wolstenholme (2009), have tried to increase productivity, efficiency and cost savings within the Construction Industry. A common theme that runs through all of these suggests collaboration is key to improving sector performance.
The Avanti project	Established by the UK Department of Trade and Industry in 2002, demonstrated that the use of co-ordinated information and working collaboratively can bring about significant advantages, namely efficiency and cost savings.
UK government construction strategy (2011)	Stressed the need for greater use of technology and collaborative working which was formulated in the requirement for BIM as a central policy adopted in England in 2016.
Scottish procurement policy note (SPPN 01/2017)	Sets out how BIM shall be adopted within public sector procurement where appropriate. The policy states that 'The introduction of BIM is a key catalyst to improve efficiencies in public sector infrastructure expenditure and support wider productivity within the construction industry.'
The National Infrastructure Commission (2017)	Highlighted the need for the U.K.'s existing infrastructure to become smarter. The report called for a number of recommendations including a roadmap towards a national digital twin. 'High quality, standardised data on all of our infrastructure assets, along with the ability to share this securely will enable the U.K.'s infrastructure to be viewed as an interdependent, dynamic system.'

As Scotland moves towards a digital built environment, Building Information Modelling (BIM) is seen as a key part for the future of the Scottish construction industry. Significant savings and benefits have been confirmed and demonstrated through the use of BIM on a number of Pathfinder Projects in Scotland (Kumar 2017), including the M8/M73/M74 Road improvements, Marischal Square mixed used Development, the Royal Hospital for Children & young people and the Edinburgh Castle Main Palace Retrofit (1).

BIM is a collaborative process that is enabled by technology and supported by people. Collaborative working involves tasks being carried out in a particular order for the mutual benefit of all. It is within a collaborative working environment that teams produce information using standard processes and agreed standards and methods. This ensures data can be communicated, reused and shared efficiently, without loss, change or interpretation. *A CDE is a technology solution to enable this collaborative way of working*.

Essentially collaborative working means everyone benefits more than they would individually. Everyone reduces waste, generates more money and creates a better environment.

Through improving data management and collaboration within projects, this will support the industry to deliver greater efficiencies through the design, construction and operational stages of a project. A CDE is a fundamental part to deliver BIM by providing a digital repository to store, manage and engage with project information. (Figure 1-1).

(1) - SFT BIM Pathfinder Research - https://www.scottishfuturestrust.org.uk/storage/uploads/pathfindersreportfinaljuly2017.pdf

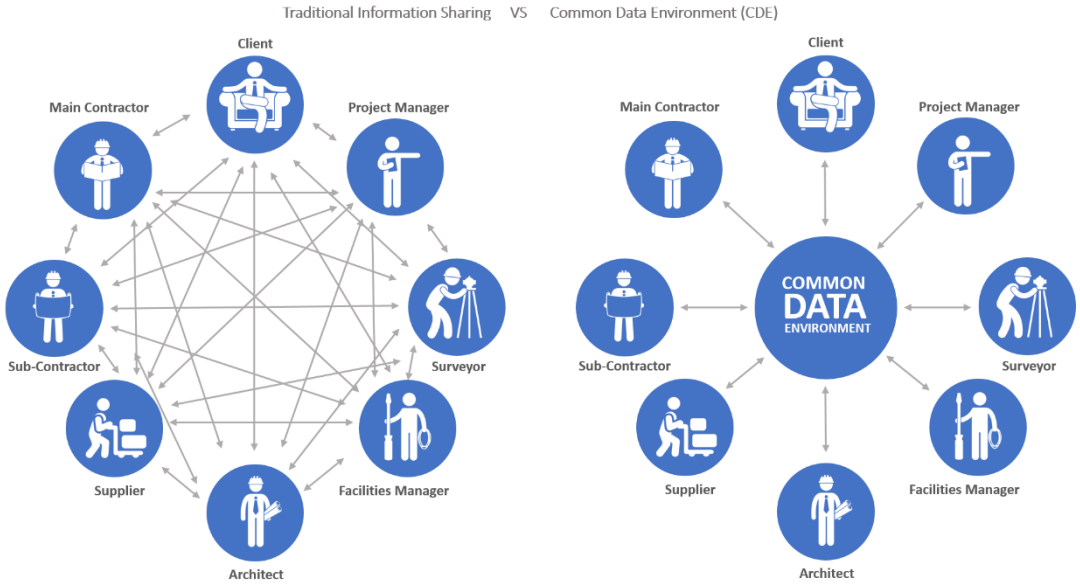


Figure 1-1 CDE Concept

1.1 BIM and collaborative working

The definition of BIM maturity was originally developed as part of the UK government BIM strategy (2011), with their BS BIM level 2 suite (PAS1192 et al) providing the fundamental principles in the production and management of information models in a secure and collaborative environment. Later this year (2018) an updated set of documents will be published taking into consideration the evolution of managed methods of working over the last five years. BSI has never formally defined BIM level 2 maturity, however it is commonly understood to be a series of domain and collaborative federated models. These models consist of both 3D geometrical and non-graphical data and are prepared by different parties during the project life-cycle within the context of a common data environment. Using proprietary information exchanges between various systems, project participants will have the means necessary to provide defined and validated outputs via digital transactions in a structured and reusable form.

Information models are progressively developed across the project lifecycle. The Project Information Model (PIM) is developed during the design and construction phase of a project. In contrast the Asset Information Model (AIM) is at the operational stage for all the assets in an Employer's portfolio or estate (Figure 1-2). Information models are a combination of Graphical information (such as 3D and 2D models a geometry), non-graphical data (such as schedules and specification) and associated documents (such as manuals and warranty's (Figure 1-3).

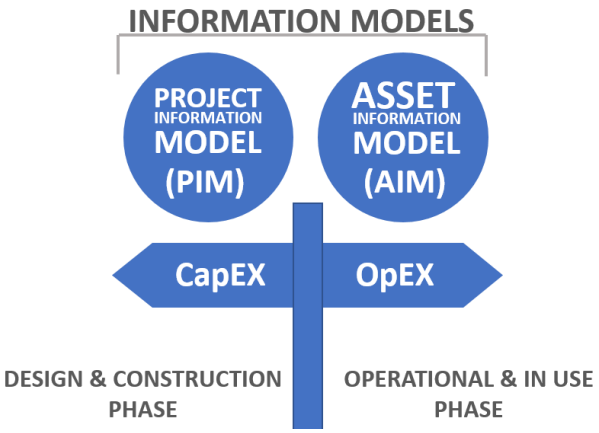


Figure 1-2 Information models PIM & AIM

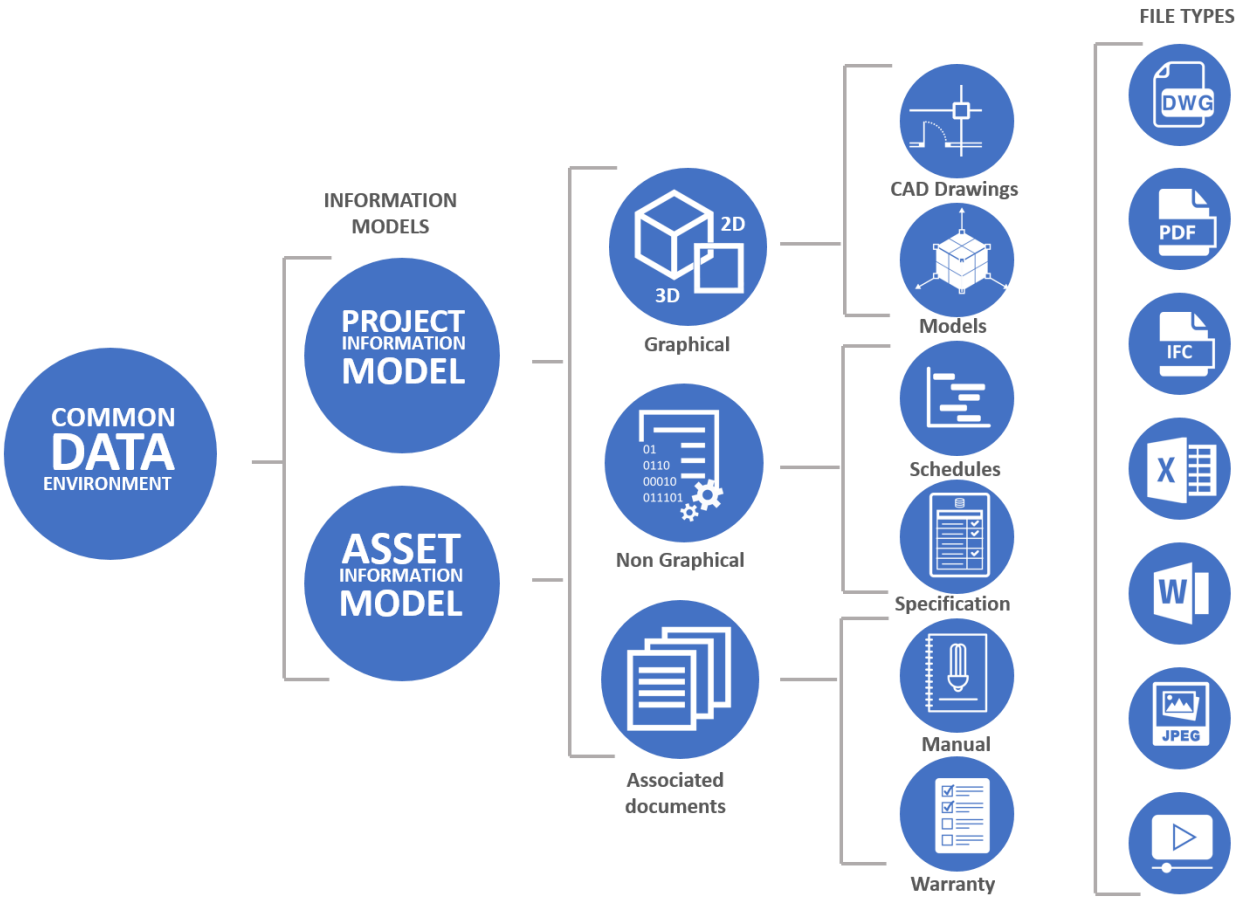


Figure1- 3 Common data environment types and content summary

To achieve BIM level 2 and embed it as 'business as usual' within the industry, this will rely on a firm grounding built upon the implementation of BIM level 1. This level of maturity is built around BS 1192 (BSI, 2007). The fundamental principles requires information to be shared within a CDE together with a suitable information hierarchy to be agreed upon which supports the concept of the CDE and the document repository. Essentially a CDE is simply a digital place in which the information comes together. With vast amounts of digital data being created and shared during a project's lifecycle, the CDE becomes an ideal environment in which to promote a collaborative working culture. Regardless of the Level of BIM maturity, the CDE should be a main software priority within any organisation wishing to work within a BIM enabled environment.

1.2 What's in a name?

Collaborative technologies is a wide encompassing term that is used to describe software and hardware solutions or a combination of both that help people collaborate digitally. There are many different examples of technologies that help us collaborate which may be commonplace within organisations currently. Video and web conferencing facilities, instant chat and messenger systems, online meeting spaces and portals and intranet applications to name but a few. All of these technologies and applications have the same thing in common, in that they allow us to communicate and collaborate more effectively regardless of our geographic locations.

Using collaboration technology does not necessarily mean that we are collaborating. Collaboration is an activity and not a technology, and therefore we must think of collaboration technologies as an enabler that allows collaboration to take place only when we as human beings are prepared and equipped to do so. (Wilkinson, 2005).

PAS 1192-2 (2013) defines the CDE as ***'a single source of information for any given project or asset, used to collect, manage and disseminate all relevant approved files, documents and data for multidisciplinary teams in a managed process'***. The standard states that for the avoidance of doubt all project information, whether in BIM environments or in conventional data formats, should be shared using a single collaborative data environment. This may use a project server, an extranet, a file-based retrieval system or other suitable toolsets.

In reality, a successful CDE solution may require a combination of technologies that work, interact and interface with one another to provide the required functionality. For example, any software solution will also require supplementary technologies to support it; such as a monitor, hardware, networking and Internet connections. It may not necessarily be a single CDE, rather a combination that allow the project team to work together outlined in section 2.0.

1.2.1 What is a Project Server?

A project server is a computer that provides data to other computers. As the name suggests, a server 'serves' data to systems on a Local Area Network (LAN) or a Wide Area Network (WAN) over the internet. A server doesn't require any specific hardware with most regular computers being able to function as a server, however they will use dedicated software. (e.g. Microsoft Windows Server) It is important to make sure that the server has the appropriate processing speed, storage space and Random Access Memory (RAM) to make them efficient and effective. Larger organisations may use a dedicated rack mounted hardware.

1.2.2 What is an Extranet?

Many organisations and companies will use an intranet typically to publish webpages regarding company events, health and safety policies and staff newsletters. Increasingly they are also used as a way to access training, submit timesheets and request holiday, all reducing time and paperwork. The intranet is a private network which uses internet technologies. However, it is isolated and protected from the global Internet by the way of firewalls and logging credentials. Anyone wishing to access the intranet outside of the organisation can often use a VPN (Virtual Private Network), encrypting communications between the intranet and the user's personal computer.

Extranets are similar to intranets but with the ability of being accessed by authorised people from different organisations. (Figure 1-4) An example of this could be a hospital that provides local General Practitioners (GPs) with access to a booking system so they can make appointments for their patients. Efficiencies are gained as all GPs have access to the same data in the same format. Information is isolated from all other internet users and without granting access to an organisation's entire network. Furthermore, communications can be encrypted over a VPN.

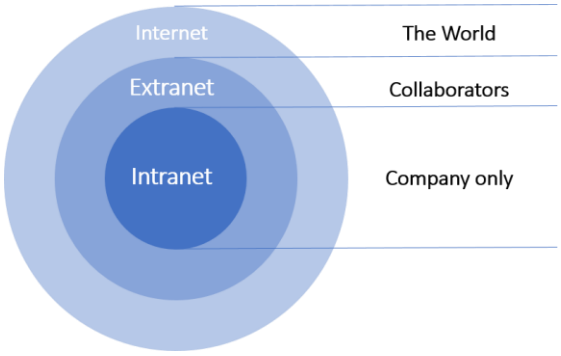


Figure 1-4 Internet, Extranet and Intranet

Within the context of a CDE for the built environment, project extranets are set up (often temporarily) for a specific project purpose. They are essentially an extension of an organisation's intranet that is extended to users outside of the organisation such as partners, vendors and suppliers to access and share project information within a closed system. This means users will require a user ID and password permissions to access. Multiple organisation or teams, based in different geographic locations, each use their own IT system. Rather than have localised data held by individual team members or organisations, data is held in a centralised repository or data store. This can be accessed by authorised people using a common dominator technology, such as a computer, internet connection and web browser and without the need or licence to run the particular software application which generated the file in the beginning.

1.2.3 What is a file based retrieval system?

File based retrieval systems work by performing a query or search against a set of free-text records. A simple example is the World Wide Web and performing a search via a search engine. Information retrieval works by searching information within a document, a document title or by searching for metadata and returning a match based upon the stated query or search criteria.

1.3 What does a BIM CDE actually mean?

Project servers, extranets, and file retrieval systems are only effective if used with appropriate data structures and workflow. The CDE provides the mechanism for making the project information available to the team. It also allows for a managed workflow for the creation, sharing and re-purposing of data.

A British Standard in relation to BIM, PAS 1192-2 (BSI, 2013) provides a logical framework for the production of pertinent information at discrete stages of the whole building lifecycle. Its focus is on BIM in the delivery phase of a project and the Project Information Model (PIM). PAS 1192-2 (BSI, 2013) should be read alongside BS 1192:2007 + A2:2016 (BSI, 2007) which outlines the use and structure of the CDE. BS 1192 (BSI, 2007) describes the four distinct sections of a CDE highlighted in figure 1-5 and gives details on naming, numbering and identification of all data that is held in the CDE. Table 1-2 highlights the functional sections of the CDE and figure 1-5 shows the key statuses of deliverables in line with BS1192 (BSI, 2007).

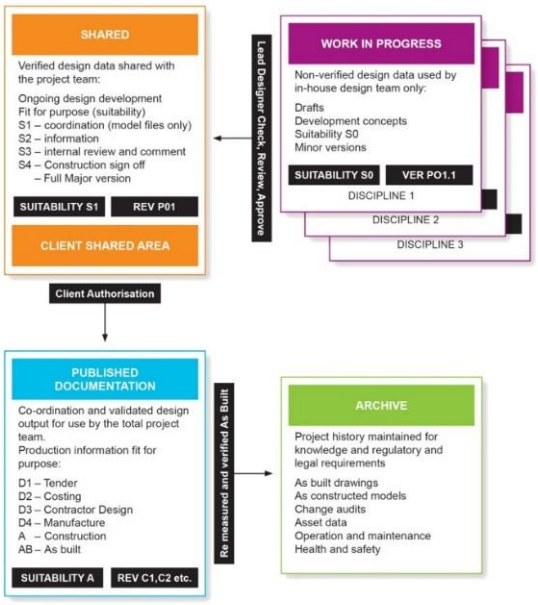


Figure 1-5 Key statuses of deliverables in line with BS1192:20017

Table 1-2 Functional sections of the CDE – Processing work through the CDE

Section	Description
Work in progress	Area of the CDE where team carries out their own work using their organization's software systems. Non-verified design data used by in-house design team only:
Shared	Area of the CDE where the team shares verified design data with other members of the project team.
Published	Area of the CDE for coordination and validated design output for use by the total project team.
Archive	Area of the CDE for project history maintained for knowledge and regulatory and legal requirements. It is also a repository of the project information for non-asset portfolio employers.

1.4 The Objectives and Benefits of a CDE

The CDE has two key fundamental objectives.

1. To allow everyone access to up-to-date, reliable information in a structured and easily accessible format about a built asset which will help in the occupational phases of the asset within the OpEx stages.
2. Support the management, creation, assurance, sharing, dissemination and co-ordination of information generated during major works, minor works and maintenance activities.

The CDE is used throughout the whole project lifecycle, including asset design, delivery and the management. A further British Standard for BIM, PAS 1192-3 (BSI, 2014a) describes the Asset Information Model (AIM). It is focused on how to integrate the management of information across the operational stage of an asset. This document takes the BIM Level 2 processes and develops them for use to support the operational life of assets.

There is often a misconception that BIM is 3D CAD or is just a 3D modelling software package. Unlike traditional 2D CAD information which is essentially lines, circles and arcs on a page, information models are essentially placeholders of data represented both graphically and non-graphically. With vast amounts of digital data being created and shared during the project life-cycle the CDE becomes an ideal environment in which to promote a collaborative working culture. It becomes the central vehicle from which everyone involved in a project can access the same relevant data. With the increase of digital information there is also an increase in the risk relating to security of sensitive asset data. We discuss this later within the security requirements.

The use of the CDE provides both tangible and intangible benefits. While some benefits can be clearly quantified, others are harder to calculate. Many of the benefits will come about by the use of *digital* information as opposed to *analogue* (Paper based). An obvious example of this is avoiding costs and time of having to print out drawings and using postal service (either internal or external) to distribute information. There is less time spent searching for information and more certainty that everyone is working on the most up-to-date version of the information available. Further reductions in costs can be achieved via fewer meetings and reduced travel time.

Using shared digital information within a CDE and the associated automation, the need for rework associated with errors is reduced. However, the conundrum remains: how do you measure something that has not occurred? Table 1-3 highlights how added value is brought about by the CDE.

Table 1- 3 Added value brought about by CDE

Added value	How
Improved data quality and consistency	Based on a single version of the truth which ensures that the team is always working on the latest, correct version of data; improved compliance and Quality Assurance; reduction in re-work and errors
Clear ownership of data	Ownership of information remains with the originator, and although it is shared with and reused by others, it is only the originator that is authorised to change it
Easy exchange of models and data	Between project team members based on a clear data structure and common file naming convention. Create, share and access information from anywhere on any device
Clear communication of data status	Through suitability codes (i.e. what uses the information is suitable for) and CDE workflow stage
Greater reliability of data	Based on common Quality Control processes and audit trails; real-time visibility of cost, time, and quality; better decision-making through real time insight reporting
Spatial co-ordination	Inherent in the idea of using a centralized model with a consistent coordinate system being used between each constituent model.
Project team members can all use the CDE to generate the documents/ views they need	Using different combinations of the central assets, confident that they are using the latest assets (as are others).

2 Adoption of CDE's within industry

As part of defining your requirements for procuring a CDE, it is important to consider how the technology and processes required will fit; not only into your overall organisational strategy but also your BIM strategy. You should be clear from the outset of its intended purpose.

For example, will you be implementing an organisation-wide CDE solution? Will it be used by multiple departments, departmental project teams or just by selected individuals? What is the scope? Is it for a single project, a programme of projects or is it an enterprise (i.e. across an organisation) solution?

There is no single way in which to implement a CDE, and it is unlikely that the CDE will be delivered by any single product platform or system. Instead, it may be configured from a range of information management systems that are owned and operated by a number of different participating organisations. This will require the need for co-ordination between the systems employed.

2.1 Levels of CDE

Figure 2-1 illustrates the various levels of CDE and the environment that they support.

Figure 2-1 Levels of CDE

2.1.1 Organisation Wide CDE

Asset information management systems are used by asset-owning organisations. They provide simple, secure access to information for all assets in a portfolio or estate.

It can be helpful to think of the PIM and the AIM as being virtual representations of the assets themselves, containing structured information about the physical and functional characteristics of the assets. They are a collection of model files, drawings, documents and structured data in COBie format.

The AIM ideally contains information about all assets within a portfolio, or 'digital estate'; not just one. It also contains additional and sometimes different information to the PIM, based on what's needed by the Asset owner/operator. For example, some construction information may not be deemed relevant for FM/AM purposes.

2.1.2 Cross departmental Project Team CDE

Sometimes known as online project collaboration tools, these systems may be provided by the Tier 1 suppliers, the lead designer or constructor and sometimes both, at the different stages of the project. They are also used to share information across a department or project team and make up the shared and published information environment. Each project team can work with project information that is compliant with each department or organisations own security requirements.

2.1.3 Team CDE

The creation of information is controlled through the use of templates and the application of file naming conventions, revisions, versions and suitability codes, helping teams to comply with the information standards that were defined in the Employers Information Requirements (EIR) and BIM Execution Plan (BEP). Information is delivered in the Work in Progress information environment.

Each ***supplier*** responsible for the creation of information should have their own procedures to control the creation and coordination of their own files and data. It is key to better information management.

The capabilities and cost of information systems vary and the appropriate choice for the organisation will depend on the nature of the information the team creates and their roles and responsibilities. Depending on the role, basic document management capabilities such as a file server and email may suffice. However, the team may be responsible for coordinated designs and require more sophisticated functionality to bring federated files together and integrate with design applications that can satisfy BIM Level 2 requirements. In all cases, the information management systems need to be configurable to align with EIR and the BEPs on each of the projects.

2.1.4 Individual CDE

The individual CDE, provides the environment for personal information or an environment that can deliver the required applications to produce information. It is important that this environment is supported by the right supporting networking and infrastructure so that information and data can be efficiently created, developed and held securely.

2.2 A CDE Operating in the cloud

The development and decreasing costs of processing power, internet speeds and online storage have made working 'in the cloud' a viable option. The cloud is a way of storing and accessing data, software and service over the internet, rather than local storage or a hard drive. A simple example of cloud services are Netflix, Spotify, iCloud, Google Docs or Gmail to name but a few. The cloud is changing how we think about how we access information and a move from possessing content to accessing content. For example, rather than watch a film on your DVD player, or a digital copy located on your computer, films and media can be streamed from an online location or downloaded from that online location to be viewed 'offline'. This approach enables access to content any time across a variety of devices so long as there is an internet connection. In the case of

services such as Google Docs, the same documents can be accessed by multiple people concurrently – with a full audit trail of changes by each.

Scotland's Digital Future Strategy: Data Hosting and Data Centre Strategy for the Scottish Public sector (2014) recommends that the public sector in Scotland needs to prioritise cloud computing virtualisation and consolidation to deliver on future requirements. Rather than store information on private, localised, non-internet accessible servers, information is stored in the cloud, an approach that is often faster to deploy and requires less support from IT teams. Much investment has been made in the Public Sector Network (PSN) (the government's high-performance network which helps public sector organisations work together) reduce duplication and share resources. In Scotland, the PSN is known as the Scottish Wide Area Network (SWAN), which provides a single, shared network and common ICT infrastructure across Scotland's Public Sector.

2.2.1 Service models

The term 'cloud' or 'cloud computing' is used to describe a range of technologies, however these can be broadly broken down into three areas: Infrastructure as a Service (Iaas), Platform as a Service (PaaS) and Software as a Service (SaaS) as illustrated by Table 2-1.

Table 2-1 Service models

Category	Description
Infrastructure as a Service (IaaS)	A IaaS Cloud allows users to access raw virtual computer resources via across internet. Rather than procure hardware, IaaS enables users to procure access to the IaaS's hardware offering the ability to increase or decrease capacity as required.
Platform as a Service (PaaS)	A PaaS Cloud allows software developers access to a platform to develop and run applications. An example being Twitter or Facebook, whereby software developers can develop 3rd party Apps such as Games.
Software as a service (SaaS)	A SaaS cloud allows users to access software applications hosted in the cloud and accessed via the internet (as opposed to On-Premises software installed locally on an organisations computer or servers). Rather than purchasing software outright, SaaS is usually delivered via a subscription based model. For example, Audible offers access to 200,000 book titles via a monthly subscription. Books can be listened to via the Audible Cloud Player which doesn't require the user to download or install any software to run.

Today, many of the CDE vendors offer their solutions as a SaaS, hosted within a private cloud. As the name suggests, a private cloud is provided for a sole user of a cloud service (as opposed to a community cloud, or a public cloud), with access usually being restricted to a local or wide area network.

While operating in the cloud offers a number of advantages, it is important to consider the drawbacks. Any cloud-hosted solution requires a stable fast and reliable internet connection in order for your organisation to remain effective and productive. You should consider any disruption or downtime with regard to connectivity and what this may mean for your business.

2.2.2 Commercial- Off-the-Shelf (COTS)

Commercial Off-The-Shelf (COTS) are products that reduce the amount of bespoke coding required, whilst also leveraging third-party investment and future development. If bespoke development is unavoidable the strategy states that this should be restricted, where practical, to the business process layer of the architecture from where existing technical services can be consumed. Scotland's Digital Future: High Level Operating Framework (2017) provides guidance to the public sector and recommends the use of COTS.

Many COTS are highly configurable, reducing the need for custom development. If required, most vendors will offer a full design, development and implementation service for bespoke customisations, enhancements and third party integration.

2.2.3 Subscription or Perpetual licenses?

When it comes to software there are often two main considerations: Perpetual versus subscription-based models. Each has their own benefits and drawbacks.

- **Perpetual licensing** has been the historical or more traditional way in which software is purchased. The software license is paid for upfront and you have the right to use it indefinitely. Software vendors usually offer an option to purchase support and maintenance contracts which are typically renewed on a regular basis (e.g. annual). Alternatively, you may wish to consider a;
- **Subscription-based model** has seen a dramatic increase due to the adoption of the cloud and SaaS. With a subscription-based model, the software is purchased usually via a monthly, quarterly or annual fee allowing access to the software during the subscription term. You do not own the software, rather you lease it by having a licence for its use. Typically, the subscription payment will include basic maintenance and hosting costs together with support services, unlike in the case of a perpetual licence in which maintenance and support is often an additional cost.

Vendors may offer different licence configurations or modules with varying features. For example:

Module/Feature	Bronze	Silver	Gold
Document management	Yes	Yes	Yes
Dash board reporting	No	Yes	Yes
Schedule integration	No	Yes	Yes
Mobile field integration	No	No	Yes

Table 2-2 Example Scope of Licence agreements

There are several different licence fee models. These may be based upon

- Project construction value;
- Per Project;
- Per user; or
- Enterprises wide (unlimited users)

Licence considerations include:

- ☐ Ownership – Is it important that you own the licence to use the software rather than lease it?
- ☐ Upfront payment - Do you have the available cash flow to fund an upfront software cost? What is the initial subscription term?
- ☐ Flexibility - do we require flexibility and scalability of licence in line with demand?
- ☐ Can additional user subscriptions be purchased during the contract period, if required?
- ☐ New releases – Is it important that you have the latest software and release?
- ☐ Deployment time - how quickly do you need to be up and running? Cloud-based software is deployed and implemented over the Internet rather than having to be installed on a physical server or on each and every user computer or device making it faster.
- ☐ Any set up fees?
- ☐ Excess storage fees?
- ☐ Additional user subscription fees?
- ☐ Is backup and disaster recovery included?
- ☐ Is a fully managed hosted solution included?
- ☐ Is support and maintenance included?
- ☐ Does it include SSL encryption?
- ☐ Licence fee per project?

2.2.4 User Support & Maintenance

The amount and level of support will vary depending upon your organisations operational hours. Typically, most vendors will provide some sort of self-help guidance in the form of online videos, frequently asked questions (FAQs) or downloadable documentation. It is important to consider any downtime due to a disruption to the vendor service and what this would mean to your organisation. It is worth discussing with potential vendors and suppliers what compensation or user credits are given in response to any service delivery failures. Other considerations in relation to support are listed below:-

User support and maintenance considerations

- ☐ Phone, email, webchat or online ticket support?
- ☐ Online training, webinars self-help instructional web pages and videos?
- ☐ Onsite training courses?
- ☐ What support and response time is required? 24 hours 7 days a week? 9-5 (local time) Monday – Friday?
- ☐ Bank holidays?
- ☐ Levels of support priority? From down and non-accessible to non-disabling issues?
- ☐ Onsite support required?
- ☐ Is support available to third parties?
- ☐ Does support package include maintenance, upgrades and bug fixes?
- ☐ When and how are scheduled maintenance performed? What impact does this have on BAU?
- ☐ What is the availability commitment and uptime?

3 CDE functionality

CDE solutions range in price and functionality. It may be likely that the CDE solution is a combination of multiple software products (sometimes referred to as a 'technology stack') as opposed to a single product. While some file management systems such as DropBox offer a 'freemium' service, they may not comply with PAS 1192:2 (BSI, 2013) and BS 1192 (BSI, 2007). Other features within a CDE may include document control, instant messaging and the ability to mark up and review model files directly within the CDE.

Figure 3-1 illustrates the core characteristics of document and data management systems solution.

Figure 3-1 Core characteristics of document and data management systems solution

	Function	Examples
	File Publication	- Automated PDF generation - File synchronisation to check-out and lock files and check-in new revisions
	Document Management File management should meet the requirements for aspects such as naming conventions, document numbering, status fields, documents types, revision sequence and metadata classification.	- Customisable folder structure with highly controlled access - Upload, record, store internally, share and review documents - Bulk upload capability - Downloading of large packages of information, including bulk file download and zip files - Ability to define document naming rules Audit trail and version management - Workflow engine to automate and control the review and approval process - Document Control and Document Actions via workflow engine - Creation of organisation-specific forms, headers, footers, disclaimers, and correspondence templates, specific document types
	Data Security	- Encryption - Access controls - 2-Factor Authentication (2FA)
	Search Capability Such navigation functionality enables you to locate projects, assets, document files, model files and data within a workspace and across works spaces.	- Search engine including full content search (ability to search text within documents)
	Reporting/ Dashboarding Dashboard interfaces alert users of any updates or changes to information and a summary of incoming and outgoing tasks. Ideally functionality should allow for customisable reports as well as predefined reports to allow for flexibility in reporting on a number of aspects required.	- Customisable dashboard with live performance data - Customisable reporting functionality - Automatic notification triggers
	Information viewing capabilities	- Integrated red-line and mark-up tools - Word processing and spreadsheet documents - PDF Documents - CAD/CAM Files - BIM 3D (including IFC) - Digital images
	Mobile and field support	- Field viewing and data logging capability on mobile devices
	Integration potential	- Integrated working with word processing and spreadsheet documents - Integrated working with CAD Systems e.g. automated title blocks - Web-interface - Email integration

Table 3-1 Core functions

3.1 Open data formats

Data and information feeding into the CDE will have been authored in different software platforms and file formats. Information viewing capabilities can allow you to view common industry file formats (IFC) without the need to run the native application it was created from. Some will allow you to view and federate models in an open file format or a proprietary file format. Intuitive controls allow the user to navigate around the model allowing components to be easily recognised and associated data and documents viewed.

4 Considerations in the procurement of a CDE

A CDE is not just a technology solution but is a combination of software and processes. Information standards need to be agreed to be implemented so that information can be easily managed, retrieved and used within the CDE. The benefits – both qualitative and quantitative – will not arise purely from the CDE technology solution but the amalgamation of the following:

- BIM Level 2 standards;
- Information Management processes;
- Form of contract;
- Culture and behaviour; and
- Applied technology of the CDE.

Scotland's Digital Future: High Level Operating Framework (2017) provides a collection of I.T. architecture principles. A key principle is the encouragement of the reuse and sharing of existing assets before buying and building new ones. With this philosophy in mind it is worth considering the current technology stack and software capabilities. As part of the procurement assessment into a CDE solution may find that current technology solutions functionalities could be further exploited or adapted to suit.

4.1 System / Platform considerations

To procure the right solution for your organisation, you need clarity regarding what you want to achieve with the use of a CDE. You should start with the end in mind and understand what a successful solution would look like and what benefits it would bring.

Key system/platform considerations include:

- ☐ Integration potential
- ☐ User eXperience (UX)
- ☐ User Interface (UI)
- ☐ Simplicity
- ☐ Robustness
- ☐ Performance
- ☐ Impact of use on users
- ☐ Data Security
- ☐ Reporting
- ☐ Query Engine
- ☐ Dashboarding
- ☐ Mobility
- ☐ Field use & mobile form factor devices
- ☐ Ability to 'lift and shift' data between systems
- ☐ Transparency
- ☐ History of transactions/audit trail
- ☐ Status, progress of information deliverables
- ☐ Workflows
- ☐ Flexibility & Automation

4.2 Vendor considerations

Implementing any new technology and processes can be a lengthy process. This will require working closely with your selected vendor and therefore it is important that you establish and maintain a trusting and collaborative working relationship with them.

Key vendor considerations include:

- ☐ Financial stability of vendor (and related risk)
- ☐ How well the products might integrate with each other (where multiple products were proposed as a single offering)
- ☐ Vendor development team size
- ☐ Year-on-year growth trends
- ☐ Key clients and referees/references
- ☐ Development roadmap
- ☐ Impact of system use on project teams (and their existing information management systems)
- ☐ Implementation services scope and/or methodology

4.3 Existing infrastructure

The CDE should be considered in the context of your wider IT strategy. It is important to make an assessment of any existing network, connections, software systems and hardware to ensure they will achieve the right levels of performance needed to implement your CDE solution. With many solutions, there is a need to rely on a secure and stable internet connection to enable uninterrupted use and deliver successful outcomes.

Having an early dialogue with internal IT resources will help you establish your current capability and capacity for managing and implementing a new technology stack. Implementation is likely to be phased, replacing legacy systems over a defined period of time. This is to ensure that new ways of working and the skill sets required are embedded as far as practically possible. When assessing existing software systems, it is prudent to understand and communicate with your organisation any retention or future replacement plans and how this will fit in with your chosen CDE strategy.

Existing infrastructure Considerations include:

- ☐ Do all computers have access to a local server?
- ☐ What key software is currently installed?
- ☐ Do your current systems support open data formats?
- ☐ Do they have the ability to support the push and pull of data?
- ☐ Does your existing IT architecture allow the ability to push and pull data from CDE and other systems?
- ☐ Any capacity functionally or performance issues that need to be addressed?
- ☐ Is remote access required?
- ☐ What is the required or recommended internet speed?
- ☐ Reliable Internet Service Provider (ISP)?
- ☐ Adequate line size for internet?
- ☐ Adequate internal network?
- ☐ Adequate internet connection for remote workers?
- ☐ Correct browser support?
- ☐ Applications to install?

4.4 Data Security

As the use of digital data increases, so does the threat posed to cyber security (Mordue, 2015a). To ensure that information is safe and secure, you should follow the principles set out in PAS 1192:5 (BSI, 2015a) and be mindful that sensitive projects and information will require a strict policy to be implemented regarding access and permissions.

The Centre for the Protection of National Infrastructure (CPNI, 2017) provides guidance on security considerations for CDE's, including 14 principles for CDE Implementation of cloud security. The guide offers advice regarding supplier/service providers offering certification against specific security standards.

The Senior Information Risk Officer (SIRO) or Built Asset Security Manager (BASM) described in PAS 1192-5 (BSI, 2015a) clause 6 should generally not rely on any assertions without additional assurance provided through independent validation. The CPNI further advise that independent verification should be sought to ensure that the scope and outcome of all certifications assessments are correct.

Where information in a cloud service includes personally identifiable information, in addition to applying the 14 security principles the employer/asset owner should take into consideration advice given in *Guidance on the use of cloud computing* (ICO, 2012). This sets out the need to clearly identify the data controller and data processor and highlights that additional security measures may be required to comply with the obligations of the employer/asset owner under the Data Protection Act 1998. The ICO guidance includes a checklist of points that are particularly relevant to the handling of personal data. It is worth noting however that the data protection act 1998 is soon to be superseded. (Refer to section 4.6.1).

4.5 Data ownership

The BIM Protocol (CIC, 2013) is a supplementary legal agreement that is incorporated into professional service contacts. It also sets out the various aspects of running a BIM-enabled project including aspects such as software choice, ownership or licences of models and data, file naming conventions and provision of hosting the CDE. The recent legal case of Trant Engineering Ltd v Mott MacDonald Ltd highlights that consideration and thought should be given to who is best placed to take on the responsibility of hosting the CDE and how, as the host holds the keys to the data for the entire project (Rock, 2017)

4.6 Data Sovereignty

'Scotland's Digital Future: Data Hosting and Data Centre Strategy for the Scottish Public Sector' recommends that the public sector in Scotland needs to prioritise cloud computing virtualisation and consolidation to deliver on future requirements. This requires consideration of Data Sovereignty (sometimes known as data residency) which refers to the location(s) where the data is to be physically stored. It is important to establish where the data centre resides, especially if this is located outside the local region in which it is to be used. In some instances, data centres located in different countries may be pooled together to take advantage of combined processing and storage capacity. You should consider vendors and providers that provide secure data centres, robust encryption and independent security certification, such as ISO 27001.

4.6.1 General Data Protection Regulation

From 25 May 2018 the EU General Data Protection Regulation (GDPR) will replace the current regime established by the data protection act 1998. It will be supplemented by the Data Protection Bill once this receives Royal assent. The GDPR requires businesses to protect the personal data and privacy of EU citizens for transactions that occur within EU member states. It imposes restrictions on the transfer of personal data outside the European Union, to other countries or international organisations.

4.6.2 Privacy Shield Frameworks

The EU-U.S. and Swiss-U.S. Privacy Shield Frameworks were designed by the U.S. Department of Commerce and the European Commission and Swiss Administration to provide companies on both sides of the Atlantic with a mechanism to comply with data protection requirements when transferring personal data from the European Union and Switzerland to the United States in support of transatlantic commerce.

Personal information cloud considerations include:

- ☐ Access: Who can access the file? Is it to be set up as Private (only you or others within your organisation can view – although also possible the cloud storage provider), Public (anyone can view data without any restrictions) or Shared (only those invited can view the files)
- ☐ Password protection: For example, strong passwords using a combination of upper and lower case characters, symbols, avoiding common words and personal information
- ☐ Encryption: Suitable provisions for encryption of data.
- ☐ Privacy notice: Clear and transparent terms and conditions and privacy notices by cloud storage providers explaining how data and personal information is secured and what they will or will not do with it.

4.7 Procuring correct number of users, size of data

The number of users and size of data required should be considered early and you should assess how many projects that you are likely to undertake or maintain on an annual basis. As well as your own internal staff requirements, you should also consider other stakeholders such as the external project team, client side, contractors and suppliers that you will be working with. The very nature of collaborative construction projects means that people will join and leave during the lifecycle of the project. Not having enough licenses or storage (or and capability to increase or decrease) will prohibit collaboration and require additional functionality to be added to the existing contract.

As part of a subscription model, vendors may include periodic service reports, showing how often the software and support services are being used, storage space used and unplanned server downtime instances or performance issues.

Number of users , size of data considerations include:

- ☐ How many projects do you undertake?
- ☐ What is your future pipeline of work likely to be?
- ☐ Do other collaborators require access?
- ☐ Do you require unlimited number of system users?
- ☐ Do you require unlimited number of projects?

4.8 Disaster recovery policy and requirements

While the digitization of information and data brings about many benefits, it also presents a number of risks. It is important to consider a Disaster Recovery (DR) strategy which includes a set of policies, tools and procedures to enable the recovery and/or continuation of vital technology infrastructure and systems following a disaster (whether natural or human induced). The backing up of data is essential practice and should be carried out with disaster recovery in mind. Within your strategy, you should consider the various solutions available and what data recovery time is most appropriate to your organisation to allow for the continuation of critical business operations in the eventuality of disruption.

Disaster recovery policy and requirements considerations include:

- ☐ Is data or parallel disaster site located at a suitably geographically distant site?
- ☐ How often and when is the site updated or synced?
- ☐ Is data backed up and where is this stored?
- ☐ How are incidents reported and handled?
- ☐ Is there a recovery plan?

4.9 End of the contract data extraction

The ability to recover your data at the end of an agreement or contract with a vendor is a critical consideration. There may be a need in the future to transfer data from one CDE to another. For example, retiring legacy systems, moving from one software vendor to another or even in the unfortunate event that a software vendor ceases to support a particular product or even ceases to trade. Considerations should also be given to the form in which you retrieve your data and when. Typically, data extraction will range from simple document check-out procedures to using bulk export utilities.

Typically, vendors will retain data for a minimum term from the date of termination (e.g. 12 months). At the end of the contract process consider if the vendor will provide a database or file repository. Do you require the ability of archiving data? (this may require an additional subscription) You should engage with the vendor before the end of the contract to ensure a smooth transition of data. This is an area that should be included within the vendor contract.

5 CDE's during the operational stage

Once in the operational stage of an asset, the AIM CDE is used to specify, collect, assure, store, present and exploit information to help with the operational and maintenance phases. Asset owners in the UK should procure Information and data within the AIM CDE using the following standards, BS 1192 (BSI, 2007), PAS 1192-2 (BSI, 2013), PAS 1192-3 (BSI, 2014a), BS 1192-4 (BSI, 2014b), PAS 1192-5 (BSI, 2015a), BS 8536-1 (BSI, 2015b) and BS 8536-2 (BSI, 2016).

Objectives for the implementation of an Asset Information Model CDE include:

- Reduced costs – as a result of the automated transfer of accurate, complete and co-ordinated searchable data at asset handover;
- Better organisational and strategic planning – from more complete and accurate asset information;
- Cyclical data cycle (i.e. use and re-use) with an intelligence feedback loop;
- Better information - quality and speed of new workflows because of automation, compared to traditional workflows, and;
- Portfolio analysis - Ability to view and analyse data across the entire asset portfolio that is maintained and stored within the AIM.

An enterprise level AIM CDE is a major investment for an organisation and should go through a detailed business case to determine functional requirements and integration with other systems before instigating a procurement process. This strategy allows the employer a view of their information across their estate and supports the information processes identified in PAS 1192-3 (2014a). It is important to consider scalability of the AIM CDE solution so that it can be used to manage information on multiple projects at any time, including capital delivery projects, refurbishment, minor works, operation and maintenance contracts.

Information and data stored within the AIM CDE helps inform decision-making, optimise use and maintenance strategies. It becomes an essential source of information and data representing the physical and functional characteristics of the asset, such as

- cost and performance,
- specifications,
- operational and maintenance services,
- health and safety,

Data is exchanged within the AIM CDE and extracted into a data store. BS 1192-4 (2014b) defines the approach to be used when transferring this information via the COBie (Construction Operations Building information exchange) scheme. COBie not only allows for a good way to manage and exchange data during the project lifecycle but is also useful during the handover, maintenance and in-use phases. It is focused on maintainable assets'– that is, assets which will require maintenance, regular inspection and checks and in some cases, replacement parts (Mordue 2015b).

Figure 5-1 illustrates how information from the CDE follows a defined process during the capital delivery phase. Once information is verified & validated and accepted, information can pass to the AIM CDE during the operational phase.

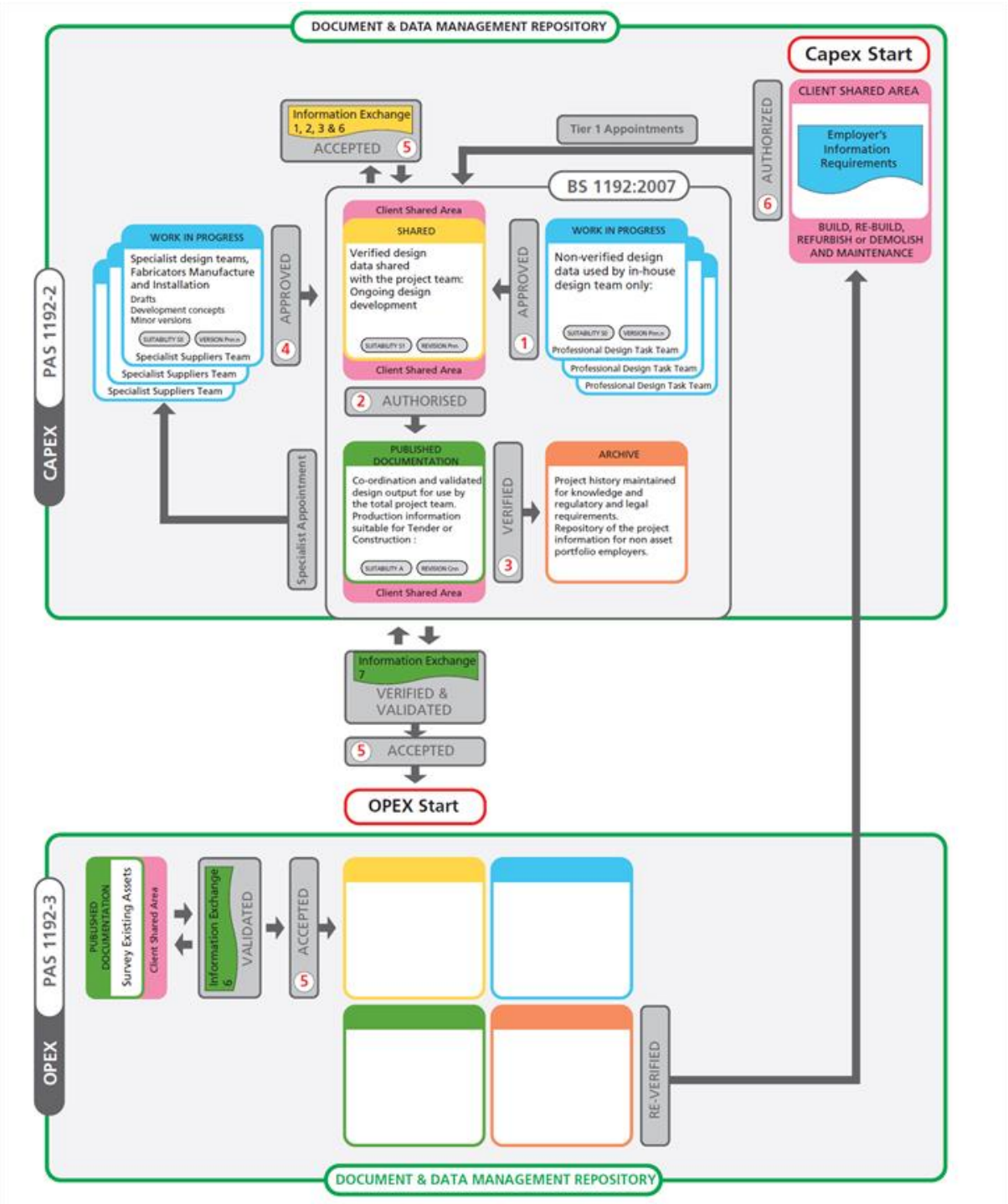


Figure 5-1 Relationship of PIM CDE to AIM CDE

6 Highland Councils procurement of a CDE – Case Study

Highland Council (HC) first investigated the application of BIM in 2013 and subsequently began to raise awareness within the council of the benefits of a CDE, develop a business case and complete the procurement of an enterprise level system. In parallel to this, HC were also responding to the Scottish BIM Programme which commenced in Sep 2014 and led to the issuing of Scottish Government Policy in April 2017. The procurement of an organisational CDE was a key part in the councils drive to implement BIM. Below are a number of lessons HC captured in the procurement of a CDE.

6.1.1 Detailed information requirements

In Summer 2015, HC issued a Prior Information Notice (PIN), published in the OJEU setting out the HC's intentions to procure a CDE. Initially, 30 organisations ranging from SMEs to large multi-national vendors, expressed an interest. In order to get best value from the resulting solution, HC started with the end in mind, asking the questions: 'what do we want at the end of our journey?' and 'What will be the benefits?' When HC was finally ready to go to tender, a prescriptive tender document containing 52 questions was published with only 5-10 vendors submitting a response. While initially many vendors expressed that they could deliver a CDE solution, through HC's detailed requirements an appropriate shortlist of potential vendors could be identified. As part of the tender questions to suppliers, HC had a number of questions which would result in a pass or fail. This included the provision for unlimited users, unlimited projects and unlimited storage capability. Potential tenderers were discounted if they could not provide this provision.

6.1.2 Procurement

The procurement strategy sought to maintain compliance with best practice but also enable the council to fully understand the tenderers proposals and score each submission fairly and effectively.

When selecting an appropriate solution, it is difficult to decide based upon a brochure or website. What is needed is a demonstration to ensure that the product will meet the councils need. The offer by vendors of free limited trial periods of the software to test its use, was not seen as a viable approach to assess the tenders. A compromise was made whereby each shortlisted vendor had 3 ½ hours to demonstrate their solution against a set of pre-determined questions. It was important to HC that the vendor's demonstration was undertaken by a user of that product or system rather than just a sales person.

6.1.3 Phased roll out

With the implementation of any new technology it is important that adequate time is given to staff to embed any new processes, change management or additional skills needed. Although the resulting selected technical solution offers many features and functions, the approach was taken internally that the council would aim to implement BIM level 1 first before moving on BIM level 2.

This meant using the CDE for uploading and downloading documents, revisions and version control and using consistent naming conventions to provide the firm foundations of information management. At a later date HC will start to think about using the CDE solution for model federation and also additional functionality such as discussion forums.

6.1.4 Software as a Service (SaaS)

The resulting CDE solution selected was a SaaS, allowing users to connect with a simple internet connection. This mitigated any firewall issues, and VPN login, as long as a user can get to the net they can access the CDE. This further meant that as the solution was fully deployed across the web and that every user has access to the same version of the software. Although there is no installation of software required HC still have an internal resource to help maintain and set new users up.

HC covers a large geographical area and at times, internet connection speed can be varied and less than optimal. It is worth taking this into consideration if using a SaaS model and being mindful of any times in which

access to the software is critical. In the case of HC, noticeable dips in internet performance occur during specific times of the day (i.e. lunch) depending on the volume of traffic across the network.

6.1.5 Security

HC have followed the principles set out in PAS 1192:5 (BSI, 2015a) as far as reasonably practical. It is important that certain types of information have relevant security clearance requirements. For example, while all project team members need to access project information, it was important that consultants couldn't see one another's costs or fees for example.

6.1.6 Additional benefits

HC have found added value in the CDE solution over and above what was originally anticipated. One example is that the CDE is now used for non-construction related projects.

Another example of additional value has been in the area of help desks. Within the tender documentation HC only required a helpdesk to be available during core working hours from 8 AM till 6 PM. As the CDE vendor has customers across the globe, HC were able to access a 24-hour helpdesk, over and above their minimum requirement.

7 Recommendations in how Public Bodies implement CDE's

Table 7-1 Key recommendations

Driver	Description
Existing processes and assessment	Map the current processes you have. Understand what a CDE is looking to do in a context of BIM and wider organisation taking into consideration your current technology stack and existing infrastructure. This will help identify any gaps in your existing processes, technology and skill base. As part of the procurement assessment into a CDE solution you may find that current technology solutions functionalities could be further exploited or adapted to suit.
Complex IT procurement challenges. (Clear brief/compliance to existing IT procedures)	Take time to detail the functional requirements that are needed from a CDE. This should take into consideration, security, functionality and user requirements. If making use of a fee limited period trial isn't an option, consider asking shortlisted vendors to demonstrate their solution against a set of pre-determined questions.
Varied CDE market offerings	With varied offerings and capabilities in CDE solution on the market, it is unlikely that the CDE will be delivered by a single product platform or system. Consider integration between different systems employed if multi solutions are to be deployed.
Varied approaches to CDE implementation	Make sure the Right people are involved in the implementation. This includes executive sponsor/senior leader, I.T. Project administrator – setting users up. Consider a phased roll out to allow adequate time to embed new technology, skill sets and ways of working. This may require using the solution on a pilot project or only using limited software functionality until a common baseline competency level is reached across the organisation.
Cost and resources to procure a system	The cost of a CDE solution will involve a number of costs over and above the software its self. Consider costs for the actual system along with any consultancy, training or data migration that may be required.
Maintain security of data	As the use of digital data increases, so does the threat posed to cyber security. Consider security minded processes set out in standards such as PAS 1192:5 as well as consideration to data sovereignty.

8 List of CDE developers

The list below is not exhaustive but provides some of the more active CDE providers within the built environment. When procuring a CDE, the contracting authority may seek to openly advertise any contracting opportunity and also carry out their own market analysis of suppliers.

Name		Website
aconex	Aconex	https://www.aconex.com/
AEC Hub	AEC Hub	https://aechub.io/
ASITE Get to it	Asite	https://www.asite.com/
AUTODESK	Autodesk BIM 360	https://bim360.autodesk.com/
Bentley	Bentley ProjectWise	https://www.bentley.com/
Clearbox	Clearbox BIMXtra	https://www.clearboxbim.com/
ecodomus	EcoDomus	http://ecodomus.com/
GRAPHISOFT BIMcloud	Graphisoft	http://www.graphisoft.com/bimcloud
revizto	Revizto	https://revizto.com/en/
Trimble	Trimble Connect	https://connect.trimble.com/
VIEWPOINT	Viewpoint	https://en-gb.viewpoint.com/
groupbc.com	GroupBC	https://www.groupbc.com/
3D REPO	3D Repo	http://3drepo.org/
FM180 BIM 4 FM consultants	FM180	http://www.fm180.com/

9 Abbreviations

List of abbreviations used in this document

Abbreviation	Term
2FA	2-Factor Authentication
AIM	Asset Information Model
BEP	BIM Execution Plan
BIM	Building Information Modelling
CPNI	Centre for the Protection of National Infrastructure
COTS	Commercial Off-The-Shelf
CDE	Common Data Environment
CAD	Computer Aided Design
COBie	Construction Operation information exchange
EIR	Employers Information Requirements
GDPR	EU General Data Protection Regulation
HC	Highland Council
IaaS	Infrastructure as a Service
LAN	Local Area Network
PaaS	Platform as a Service
PIN	Prior Information Notice
PIM	Project Information Model
PSN	Public Sector Network
SWAN	Scottish Wide Area Network
SaaS	Software as a Service
BSI	The British Standards Institute
BIM DG	The Building Information Modelling Delivery Group
VPN	Virtual Private Network
WAN	Wide Area Network

10 References

British Standards Institution (2007) BS 1192:2007+ A2 (2016), Collaborative production of architectural engineering and construction information – code of practice.

British Standards Institution (2013). PAS 1192-2 2013, Specification for information management for the capital/delivery phase of construction projects using building information modelling.

British Standards Institution (2014a) PAS 1192-3:2014, Specification for information management for the operational phase of assets using building information modelling.

British Standards Institution (2014b) BS 1192-4: Collaborative production of information. Fulfilling employer's information exchange requirements using COBie. Code of practice

British Standards Institution (2015a) PAS 1192-5:2015 Specification for security-minded building information modelling, digital built environments and smart asset management

British Standards Institution (2015b) BS 8536-1:2015 Briefing for design and construction. Code of practice for facilities management (Buildings infrastructure)

British Standards Institution (2016) BS 8536-2:2016 Briefing for design and construction. Code of practice for asset management (Linear and geographical infrastructure)

Cabinet Office (2011) Government Construction Strategy, May 2011 https://www.gov.uk/government/publications/government-construction-strategy

Centre for the Protection of National Infrastructure (2017) Common Data Environments A Guide for BIM Level 2.

Centre for the Protection of National Infrastructure CPNI (2017) Common Data Environments A Guide for BIM Level 2.

Construction Industry Council (2013) BIM Protocol, First Edition

Eagan (1998) Rethinking Construction, Department of Trade and Industry

ICO (2012) Guidance on the use of cloud computing

Kumar (2017) BIM Pathfinder Projects Glasgow Caledonian University

Latham (1994) Constructing the Team, London: HMSO

Mordue (2015).The common data environment The digital space where BIM data flows [Online]. Retrieved March 2018, from http://www.bimplus.co.uk/management/com8mon-data-environm5ent-dig6ital-space-where-bim/

Mordue (2015b) Deconstructing COBie: From the US Army corps of engineers to designers laptops [Online]. Retrived March 2018 http://www.bimplus.co.uk/management/deconstru5cting-co3bie-us-army-des3igners-desktops/

National Infrastructure Commission (2017) Data for the Public Good

Rock (2017) Trant Engineering Ltd V Mott MacDonald Ltd: The first steer on BIM from the courts. https://www.pbctoday.co.uk/news/bim-news/trant-engineering-ltd-v-mott-macdonald-ltd-the-first-steer-on-bim-from-the-courts/36211/

Scottish Government (2014) Scotland's Digital Future: Data Hosting and Data Centre Strategy for the Scottish Public Sector

Scottish Government (2017) Scotland's Digital Future: High Level Operating Framework Version 2

Scottish Procurement Policy Note SPPN 01/2017)

Wilkinson (2005) Construction Collaboration Technologies: An Extranet Evolution, Routledge (pp.25)

Wolstenholme, A (2009) Never Waste A Good Crisis, Constructing Excellence