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BIM for collaboration and coordination

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Abstract
Collaboration and coordination are massive factors when it comes to the construction industry. The construction industries have various parties within an organisation which have to work together to complete a project. As there are many teams within the organisations, communication is key as it could determine whether the project is productive.

Collaboration practices have not been the best in the industry as the industry has been massively paper based and with that, one team having data does not mean everyone has access to the data which may be vital for the project.

The Building Information Model has been mandated in the UK and all projects are to use a minimum of level 2 BIM. With BIM being previously aimed at building, the infrastructure sector has a lot to catch up on, BIM helps enhancing collaboration and coordination for an organisation, from visual aids to having a common data environment where everyone in the organisation can see all updated information and all data uploaded. Using the Building Information Model can help performance of an organisation as it does not only help collaboration for the organisation, but also assists with communication with the client and stakeholders. The purpose of this research is to investigate the issues the construction industry face when it comes to collaboration and how the use of a Building Information Model assists in provide better collaboration and coordination for an organisation.

Keywords
Building Information Model (BIM); Common Data Environment (CDE); Construction; BIM Implementation; 3D; 4D; 5D; 6D; 7D.

1. Introduction

The infrastructure sector is new to the BIM world, and with level 2 being mandated in the UK, the infrastructure civil sector is seeing the benefits they can gain from the use of a Building Information Model.

Collaboration between teams in the construction industry is becoming more complicated, and with collaborative practices being highly important in the industry and being essential to the success of construction projects. Recently the construction development delivery has been changing as there is a high demand in partnership with Joint Ventures and also public and private partnerships, which increases the high importance of collaboration (Akintoye, 2007).

With the recognition of the importance of adopting a collaborative BIM approach, the UK Government has mandated that fully collaborative Building Information Models (BIM) is to be used for all public-sector projects. A fully collaborative BIM would contain a 3D model with all asset data and documentation linked into the model. Prior to the required BIM processes, the UK construction industry was highly document focussed. There are four levels of BIM maturity with BIM Level 2 being mandatory in the UK;

Level 0 BIM
This is the simplest of all the levels, it consists of converting paper drawings to 2D CAD drawings and the output is simply distributed along the parties by paper or electronically (NBS, 2014).

Level 1 BIM
Level 1 is a combination of 3D CAD models for concept work and 2D for drafting documents and information about the product. The CAD models are managed with the use of BS 1192:2007 and the data share electronically is obtained by the common data environment (CDE) which is usually managed by the contractor (NBS, 2014). This level is mostly being used at present even though it does not contain the collaborative aspects.

Level 2 BIM
This level is the level of BIM required by the government by 2016. It is operated by collaborative practices, all parties work on their own 3D model which is not necessary a shared model however the design information shared through the same file format allowing the organisations to be able to input data and all check on it. Each party using the CAD software should be able to access the file formats through IFC (Industry Foundation Class) or COBie (Construction Operations Building Information Exchange (NBS, 2014).

Level 3 BIM
Level 3 BIM uses a single shared model and is a fully collaborative process. All of the parties involved and use the same model accessing and changing it if required, this allows the risks to be reduced by reducing the conflict of information. This level is the governments' requirement by 2019 (NBS, 2014).

The Building Information Model has been claimed to be the future of engineering (Eastman, 2008). In the construction industry, we could say some BIM tools were being used before the UK government mandated its use, however the digital devises of BIM were mainly used to focus on specific design tasks and not used for collaboration and coordination purposes (Kiviniemi, 2008).

BIM is a collaborative process, the purpose of BIM as a collaborative process being mandated in the UK is that its collaborative practices assist in providing better design and also saving costs while providing time effective designs through improving communication between the different disciplines, clients, contractors, stakeholders, etc. the aim of this paper is to investigate the issues based on collaboration and cooperation in the construction industry and to look at the Building Information Model and how its tools can be utilised in order to improve collaboration within the industry.

2.0 Related Studies

This section includes current studies that are concerning the Building Information, topics include; BIM Implementation, BIM asset procurement strategy and 4D BIM.

2.1 BIM Implementation

The implementation of BIM is more of a business decision rather than a technical one (Smith, 2009) as the implementation of BIM provides the different parties a better way of communication and also improves the quality outcome by allowing better decision making which can lead to reduced time and cost.

Implementing BIM does not only affect the construction process but also impacts the business processes. When chosen to implement BIM, business owners need to be able to visualise the future benefits and also see the positive outcome it can have on business relationships.

BIM must be implemented in the right way, businesses should analyse the internal business process, for example they are to evaluate the type of business; whether design, construction etc. through doing this process, businesses can see if their business processes are a part of the systems and if the information provided with the model can be utilised by the different parties in the organisation (Smith, 2009).

2.2 BIM asset procurement strategy

The adoption of BIM is not one that can just happen; a BIM strategy should be in place. A BIM strategy has to be clear defining the information management processes.

There are 5 key elements to a BIM strategy which are as follows;

- *BIM based process map development*

This provides guidance on the BIM implementation plan. As previously mentioned, the implementation of BIM is more of a business decision rather than a technical one, so the business processes of the organisation has to be reviewed. The process is needed to be established and support the information delivery cycle.

- *EIR (Employee Information Requirements)*

This is where the client (Employee) provides the document indicating their output requirements from BIM.

The EIR is a very important document which is defined in PAS 1192-2 and is a pre-tender document. The aim of an EIR is to confirm that the suitable information in the appropriate format is used from the pre-contract stage and throughout the BIM process.

- *BEP (BIM Execution Plan)*

The BIM Execution Plan it thought to be a reply to the ERI. The idea of a BEP is to aid the management of information for the project.

The BEP is developed both in the pre-contract and post-contract stages. A BEP details the deliverables of the project and the requirements of the information exchange format. A BEP also includes an MIDP; Master Information Delivery Plan which includes all different aspects of the model, and a TIDP; Task Information Delivery Plan which are individual delivery plans for the different aspects of the model.

- *BIM roles and responsibilities*

The roles and responsibilities are then defined. The types of roles defined are as follows;

- Employee Representative
- Project Delivery Manager
- Project Information Manager
- Task Information Manager

Just to name a few.

- *CDE*

Finally, the Common Data Environment. A CDE is to be used throughout the project where all disciplines share information, please see chapter 4.3.

2.3 4D BIM

There are five dimensions of BIM which are as follows:

3D BIM

3D BIM includes the formation of a 3D model with asset data, this allows us to see things that are not visible on a 2D drawing, it allows clash detection to be possible and provides better visualisation including walk trough's and assists in communicating with the parties and clients (Carpenter-Beck, 2017).

4D BIM

With 4D BIM, the programme is added to the model, this makes the model time-based and allows construction planners to use simulations to view their workflows and see if they are feasible and is any changes to the work flows are to be done to allow for a faster construction (Carpenter-Beck, 2017).

5D BIM

5D BIM is where cost is added to the programme, this assists estimators in providing the impact of cost with different design schedules, allowing them to choose the most cost effective and feasible approach to save time and money (Carpenter-Beck, 2017).

6D BIM

As mentioned before, BIM assists the asset throughout its lifecycle even after construction. 6D BIM is the concept of having the asset data on the model. As-built information can be linked to the model as well as ongoing maintenance works data which can help in lowering of maintenance costs as data about the asset is already know so damages to be fixed can be prepared for (Carpenter-Beck, 2017).

7D BIM

7D and 8D BIM has been talked about, however the BIM processes have not yet been defined (Carpenter-Beck, 2017).

Figure 1 illustrates the 5 dimensions of BIM:

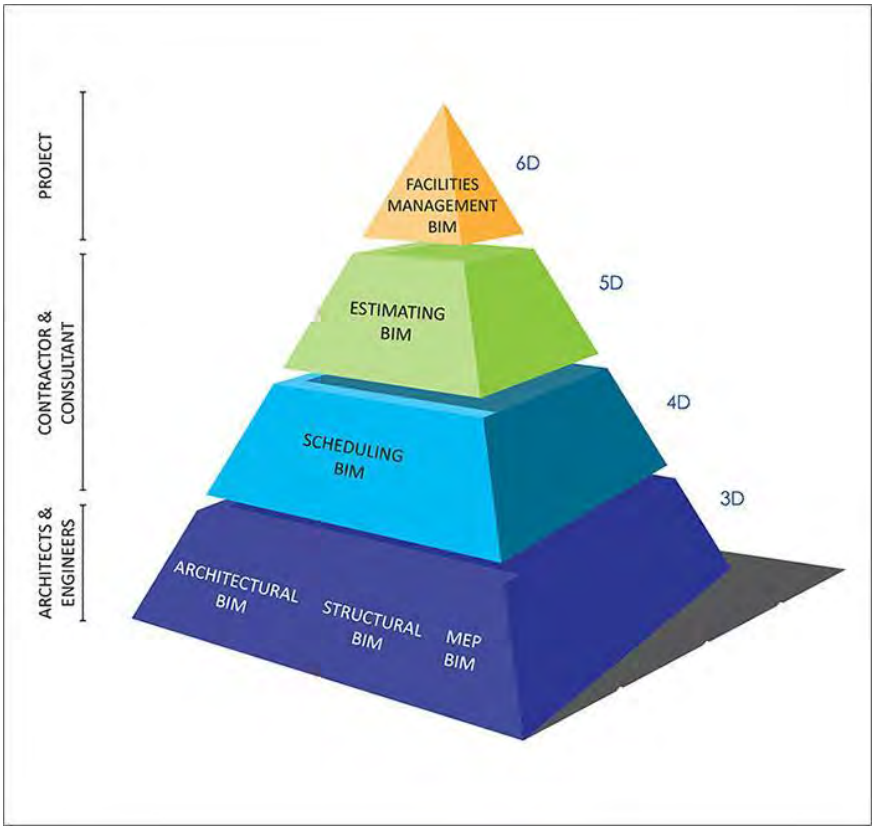


Figure 1 Dimensions of BIM

Source: (The Master Builder, 2014)

The use of 4D BIM simulations can provide various benefits t a project. With the model being linked to time, planners can utilise this to visualise their work plan. Most planners have difficulty going on site to see if their work plan is possible and without obstructions, with the 4D model, planners do not have to go on site as they can visualise the site on the model.

Having a 4D model also benefits the on-site team. With the programme being linked to the mod, the on-site team can benefit from being able to understand the work plan through visualisation rather than looking at the work plan on a Gantt chart and trying to understand how to carry out the works.

3.0 Methodology

With collaboration being an important factor in the construction industry, collaborations and coordination practices should be investigated to find better practices which can lead to improved data management and coordination.

This study comprises of a mixed method approach, identifying how the use of the Building Information Model improves collaboration and coordination in the construction industry. Case studies were observed at and semi structured interviews were also conducted.

Semi-structured interview is a qualitative method that is a combination of pre-determined set of questions which the interviewee is given the opportunity to explore a variety of responses. ***Qualitative research*** is mainly described as an empirical research. This form of research is utilised to obtain knowledge and understanding of primary reason, opinions and motivations (Wyse, 2011). This form of research provides an awareness of the issue or assists in providing ideas for the quantitative research. Qualitative research is

a method of uncovering opinions and providing a deeper insight within the problem. This method of research is obtained through the use of unstructured or semi-structures practises which mainly include focus groups, individual interviews where the respondents are selected in order to fulfil a provided part (Wyse, 2011).

A typical logic of a qualitative design was derived by Kalof is demonstrated in Figure 8, (Sengul, 2005):

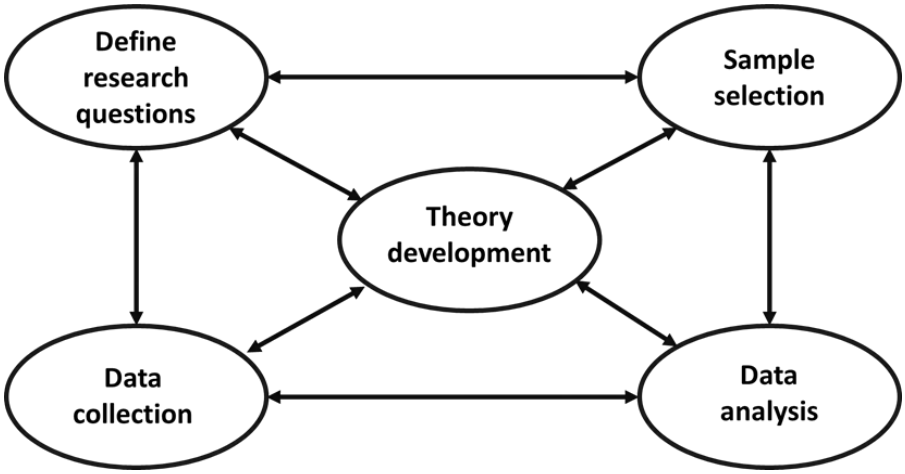


Figure 2 Overview of general qualitative research process

Source: (Sengul, 2005)

Prior to the semi-structured interviews, the research was prepared for, this was done through steps:

Literature review
A literature review was conducted understanding the collaboration practices in the construction industry and the data management practices along with the use of BIM.

Research questions
Following the literature review, the research questions were then underpinned which are as follows:

- What is the current state of collaboration practices in the construction industry?
- Do existing BIM processes assist in better collaboration?
- Is BIM worth implementing for the purpose of improving collaboration?

Interviews
Following these research questions, an idea of an interview guide was obtained. The interviews were targeted at BIM experts that have been in the industry long enough to have an idea of using how using BIM has improved previous collaboration practices.

The interviews were undertaken through phone interviews as the BIM experts are all over the UK, hence distance was an obstacle.

4.0 Results

The findings were divided into sub categories which are as follows:

- Current collaboration issues
- Collaboration practices being used
- Use of a Common Data Environment (CDE)
- Issues with BIM implementation

- BIM allowing better collaboration

4.1 Current collaboration issues

Collaboration is a team effort. And with construction projects having different teams in one organisation, it is an important factor.

From the findings, collaboration is difficult when everyone is not on the same page. Simple communication such as emails can be classed as collaboration and sharing information, however the use of BIM requires tools and electronic document management systems to achieve BIM level 2.

The main factors affecting collaboration within the construction industry are people related. Prior to BIM level 2 being mandatory, collaboration was not very well handled. With most of the work being paper based, documents could be lost and with the construction industry being busy, people on certain jobs would forget what was previously done hence loss of information.

The main factors that affect people's collaboration practices are defined in table 1:

Table 1
Collaboration Issues; People

Theme	Results
Different teams (people)	• Absence of trust • Lack of commitment • Fear of conflict • Human errors • Inattention to results

4.1 Collaboration practices in use

All the interviewees are currently using BIM level 2 within their construction projects as is has been mandated by the UK government.

BIM level 2 requires a 3D model for each of the project teams and it is operated by collaborative practices, with BIM level 2, there is still a lack of a single source of data however any data collected which would be as-built would be available to share, which enables a federated model to be created.

This brings us to our third result topic;

4.2 Use of a Common Data Environment (CDE)

BIM level 2 requires a common data environment to be available to all teams within the organisation. The findings show that all organisations are using a CDE, however it is not proving very effective.

As mentioned before, people with lack of trust and commitment may be reluctant to put data onto the CDE which is required and necessary for the BIM process to become a collaborative one.

A few of the interviewees find the CDE to be a good way of communicating. They have found that with all the project data being on one data environment, it was easily accessible and all project data was stored and when needed was easy to find and reflect on the data, whether it be for outstanding works or defects to be looked at again.

4.3 Drawback of BIM implementation

When it comes to collaboration, the difficulty is within the team. If the architect uses the model to build the design, it might not be designed to aid in construction as it may not have enough detail for the right use. (Hardin, 2015)

• *Preventing industrial hacks*

These days, the cloud has a lot of information and with the growth of cybercrime, companies using BIM have to make sure that the programme is very well secure and meet the UK Government CESG cloud Security Principles. (Mason, 2014)

• *Programmes' ability to work with other software*

With the programmes difficulty to work with other software, the company using BIM should consider how they are going to "consolidate, interpret and utilise the increasingly mountainous volumes of data" (Mason, 2014).

• *Management of the information*

BIM has a major challenge in managing the large volumes of information which are very detailed, these should be taken care of responsibly according to Hugh Boyes, Cyber Security Lead, at IET (Mason, 2014).

• *Economy and skills gap (software cost)*

Of course, with this technology, data analysts, engineers, architects and others to use the programme must be familiar with it and know how to operate BIM, however most engineers registered with the ICE (about 40%) (Mason, 2014) are over the age of 60 which would be a challenge in learning the software and is why the industry is encouraging the next generation to get into engineering. Costs for the programme include the purchasing, licence and training and the contractor may also need to update computer systems to be able to use the BIM programme.

• *More work at the start*

As BIM would require training for the prime contractors, designers and so on, it requires a lot of effort at the beginning of the project. These parties need a sit down to produce a collaborative model (Carlin, 2010).

• *Disruptive*

One of the advantages of BIM is that changes can be made easily, however this can also be a disadvantage. If dimensions of materials are checks and an order of material is made, changes to the design can be a difficulty as the order would take a couple of weeks to be delivered and if changes were made that would go to waste leading in an input for another batch of materials to suite the design (Carlin, 2010).

• *Stakeholder's software compatibility*

For the stakeholders to have compatibility, it is not necessary for them to be using the same software platform, however it is necessary for the software being used by each stakeholder to be compatible as they would be able to exchange data and files. The issue that can arise from BIM is incompatibility between software's for these stakeholders. This however has a solution, as the IFC software programme enable compatibility between BIM and other software's (Dowhower, 2010).

4.4 BIM for better collaboration

BIM can be used in several ways to enhance collaboration within the construction industry. Most of the interviewees identified various ways in which they have used both the Building Information Model and its processes and tools to improve collaboration.

The Table 2 summarises the benefits found improving collaboration through the use of BIM;

Theme	Factors
On-site team	• Visualisation through 4D; • Information gathering for construction; • Re-work reduced • Clash detection
Stakeholders / client engagement	• Visualisation • Walk through of job • Confidence gained
Overall	• Reduction of changes and errors • Improved productivity • Vital information being available to be viewed • Improved quality

On-site team

The on-site team on one of the projects found that with the use of BIM, using a 4D model made it easier for them to understand the programme produced by the planners. With the 4D model, they could visualise the work plan and understand how the works were to be carried out on site.

With the use of the 3D model the on-site team also found it very useful as they would ask the BIM team for cross sections which they used for gathering information about what is required and if it would be feasible, this pre- planning and discussion with the cross sections allowed the reduction of re-works as they would know what to expect when going to carry out works and impossible tasks can be spotted. With the use of these visual aids, it was possible for the designs to also be reviewed by the different teams in the organisation and the best solution would be chosen.

Stakeholders / clients

One of the projects in which the BIM manager was interviewed outlined how the use of BIM assisted in stakeholder and client meetings.

The BIM model was used in meeting with the stakeholders with the Traffic management proposal for the finished works, this gave stakeholders an insight as to how the traffic management was to be set up when works were on going which gave them the opportunity to communicate with the teams on if the traffic management would work or now.

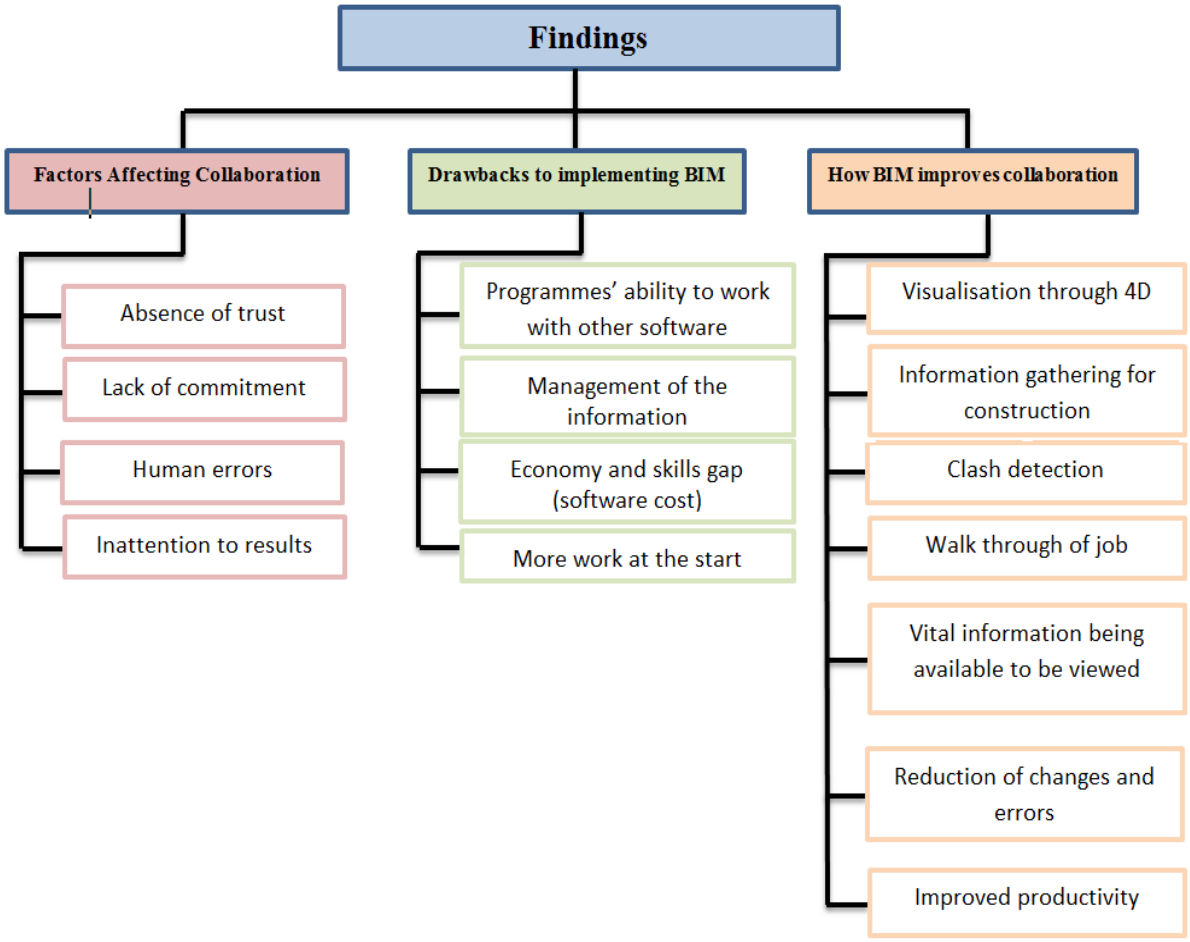
A walk through of the job was also shown, the project was a smart motorway scheme expanding a 3-lane motorway with a hard shoulder into an all lanes running motorway with ERA's (Emergency Refuge Areas).

With this walk through, clients were able to see the final product before the project was completed, allowing input from the clients to improve the projects decision making.

Overall

BIM improves collaboration overall according to the interviewees, with communication improved, this brings a lot more benefits such as reduction of changes and errors. When ideas are communicated, with the aid of the model and visualisations, these different ideas can be tested out choosing the most efficient and cost-effective solution.

The overall results of the findings are summarised in Figure 3;



5.0 Discussion

Implementing BIM will not solve all issues relating to collaboration if not implemented in the right way.

There are obstacles which were found within this research when it comes to the implementation of BIM, with BIM being a missive process, the right and compatible software is to be used. Software's used, if not compatible may prove to be an issue as if the software's cannot work together the implementation of BIM would be a difficult process.

Issues raised based on collaboration have been mainly focussed on people, with BIM, if implemented properly, the issues should be solved however with the construction industry mainly consisting of the older generations who have been in the industry for more than 20 years, they are used to their ways, the change can be difficult. Prior to BIM being mandatory, the industry was highly paper based and the change from paper based to IT based can be difficult. This change will require a lot of training at the start of implementation; the training would also only work if the training is practiced.

Although there is concern on whether the implementation of BIM is worth the costs at the start of the job, with collaboration and coordination not being a story factor in the construction industry, it would be

necessary and would allow the organisations to achieve a more cost effective and efficient way of construction leading to a more productive project.

6.0 Conclusion

The construction industry has many factors that determine good productivity. Collaboration is an important factor when it comes to high performance and productivity.

Collaboration practices have not been the best and there are a few influences that mainly affect the process leading to poor collaboration. In the industry, people are reluctant when it comes to collaboration, whether it is lack of trust or human error.

BIM tools can be used to improve collaboration and coordination in the construction industry, with visualisation being the best way of communication as people understand visuals. Producing 4D models, cross-sections, 3D visuals etc. helps communication to be enhanced within an organisation.

BIM can improve collaboration for all different parties within an organisation from the on-site team to the client. Besides producing visual aids, level 2BIM also requires a common data environment which all data is kept, hence and parties have access to all data and once updated, all updates would be available minimising loss of translation as all teams can see changes immediately.

BIM experts would recommend the use of the Building Information Model as they have found it improves collaboration and coordination within their individual organisations.

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