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BUILDING INFORMATION MODELLING - BIM

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BUILDING INFORMATION MODELLING
BIM

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This manual is part of the Construction Managers' Library – a set of books related to the wide area of management in construction. The books were created within the Leonardo da Vinci (LdV) projects No: PL/06/B/F/PP/174014; 2009-1-PL1-LEO05-05016, 2011-1-PL1-LEO05-19888, and ERASMUS+ project No: 2015-1-PL01-KA202-016454, entitled: "COMMON LEARNING OUTCOME FOR EUROPEAN MANAGERS IN CONSTRUCTION, phases I, II, III and IV – CLOEMC)". Warsaw University of Technology, Civil Engineering Faculty, Department of Construction Engineering and Management was the Promoter of the Projects.

The following organisations were Partners in the CLOEMC I Project:

- Association of Building Surveyors and Construction Experts (Belgium),
- Universidad Politécnica de Valencia (Spain),
- Chartered Institute of Building Ireland (Ireland),
- Polish Association of Building Managers (Poland),
- Polish British Construction Partnership Sp. z o.o. (Poland),
- University of Salford (Great Britain),
- Chartered Institute of Building (Great Britain).

The objective of this project was to create first, seven manuals conveying all the information necessary to develop civil engineering skills in the field of construction management.

The following manuals have been developed in CLOEMC I (in the brackets you will find an estimate of didactic hours necessary for mastering the contents of a given manual):

M1: PROJECT MANAGEMENT IN CONSTRUCTION (100),
M2: HUMAN RESOURCE MANAGEMENT IN CONSTRUCTION (100),
M3: PARTNERING IN CONSTRUCTION (100),
M4: BUSINESS MANAGEMENT IN CONSTRUCTION ENTERPRISE(100),
M5: REAL ESTATE MANAGEMENT (100),
M6: ECONOMY AND FINANCIAL MANAGEMENT
IN CONSTRUCTION (240),
M7: CONSTRUCTION MANAGEMENT (100).

The manuals created for the purposes of the library are available in three languages: Polish, Spanish and English. The manuals may be used as didactic materials for students of postgraduate courses and regular studies in all three languages. Graduates from the courses will receive a certificate, which is recognized by all organisations – members of the AEEBC, association of construction managers from over a dozen European countries.

Polish representative in the AEEBC is the Polish Association of Building Managers, in Warsaw.

Partners of the CLOEMC II project were:

- Technische Universität Darmstadt (Germany),

- Universida de do Minho (Portugal),
- Chartered Institute of Building (Great Britain),
- Association of European Building Surveyors
  and Construction Experts (Belgium),
- Polish British Construction Partnership (Poland),

Within the second part of the project the following manuals were developed:
M8: RISK MANAGEMENT (130)
M9: PROCESS MANAGEMENT – LEAN CONSTRUCTION (90),
M10: COMPUTER METHODS IN CONSTRUCTION (80),
M11: PPP PROJECTS IN CONSTRUCTION (80),
M12: VALUE MANAGEMENT IN CONSTRUCTION (130),
M13: CONSTRUCTION PROJECTS – GOOD PRACTICE (80),

The manuals were prepared in four languages: Polish, Portuguese, German and English.

Partners of the CLOEMC III project were:
- Technische Universität Darmstadt (Germany),
- Universida de do Minho (Portugal),
- Chartered Institute of Building (Great Britain),
- Thomas More Kempen University (Belgium),
- Association of European Building Surveyors
  and Construction Experts (Belgium),
- Polish Association of Building Managers (Poland).

Within the third part of the project the following manuals were developed:
M14: DUE-DILIGENCE IN CONSTRUCTION (100),
M15: MOTIVATION AND PSYCHOLOGY ASPECTS IN CONSTRUCTION INDUSTRY (100),
M16: PROFESSIONALISM AND ETHICS IN CONSTRUCTION (100),
M17: SUSTAINABILITY IN CONSTRUCTION (100),
M18: HEALTH AND SAFETY IN CONSTRUCTION (100),
M19: MANAGING BUILDING PATHOLOGY AND MAINTENANCE (100).

The manuals were prepared in five languages: Polish, Portuguese, German, French and English.

Partners of the CLOEMC IV project were:
- Technische Universität Darmstadt (Germany),
- Reykjavik University (Iceland),
- Chartered Institute of Building (Great Britain),
- AWBUD S.A. (Poland),
- Association of European Building Surveyors
  and Construction Experts (Belgium/Great Britain),
- Polish Association of Building Managers (Poland).

Within the fourth part of the project the following manuals were developed:
M20: REVITALISATION AND REFURBISHMENT IN CONSTRUCTION (100),
M21: BUILDING INFORMATION MODELING – BIM (120),
M22: OPTIMISATION OF CONSTRUCTION PROCESSES (120),
M23: DIVERSITY MANAGEMENT IN CONSTRUCTION (100),
M24: MECHANICS OF MATERIALS AND STRUCTURES FOR CONSTRUCTION MANAGERS (120),
M25: CSR - CORPORATE SOCIAL RESPONSIBILITY IN CONSTRUCTION (100).
The manuals were prepared in three languages: Polish, German and English (and additionally English version with summary in Icelandic language).
The scope of knowledge presented in the manuals is necessary in activities of managers - construction engineers, managing undertakings in the conditions of the modern market economy. The manuals are approved by the European AEEBC association as a basis for recognising manager qualifications. Modern knowledge in the field of management in construction, presented in the manuals, is one of prerequisites to obtain EurBE (European Building Expert) cards, a professional certificate documenting the qualification level of a construction manager in EU. The manuals are designated for managers - construction engineers, students completing postgraduate studies "Management in construction" and students completing construction studies. Postgraduate studies got a recognised program, and graduates receive certificates recognised by 17 national organisations, members of AEEBC.
More information:
- about the project: www.cloemcIV.il.pw.edu.pl
- about the EURBE CARD: www.aeebc.org

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LIST OF ACRONYMS:

AEC - Architecture, Engineering and Construction

AECOO - Architecture, Engineering, Construction, Owner and Operator

AIA - American Institute of Architects

BCF - BIM Collaboration Format

BEP - BIM Execution Plan

BIM - Building Information Modelling

BREEAM® - Building Research Establishment Environmental Assessment Method

bSI - buildingSmart International

bSa - buildingSMART Alliance

bSDD - buildingSMART Data Dictionary

CAD - Computer Aided Design

CDE - Common Data Environment

CEN - European Committee for Standardization

COBie - Construction-Operations Building Information Exchange

CM - Construction Manager

DfMA - Design for Manufacture and Assembly

ECMS - Engineering Content Management System

EIR - Employers Information Requirement

EU - European Union

EUBIMTG - EU BIM Task Group

GDP - Gross Domestic Product

GC - General Contractor

GIS - Geographic Information System

IDP - Integrated Data Processing

IDS - Information Delivery Specification

IFC - Industry Foundation Class

ISO - International Standardisation Organisation

IT - Information Technology

LOF - Learning Outcomes Framework

LOI – Level of Information

LOD – Level of Development / Level of Definition (in UK)

MVD - Model View Definition
NBIMS - National Building Information Modeling Standard
nD - Number of Dimensions (in BIM)
OGC - Open Geospatial Consortium
OTL - Object type library
PLCS - Product life cycle support
PSU - Pennsylvania State University
PTNB - Plan Transition Numérique dans le Bâtiment
R&D - Research and Development
SC - Steering Committee
SME - Small and Medium-Sized Enterprises
USB - Universal Serial Bus
XML - Extensible Markup Language
VDC - Virtual Design and Construction

CHAPTER 1

INTRODUCTION - LEARNING OUTCOMES

(J. SNÆBJÖRNSSON, I. KJARTANSDOTTIR, P. NOWAK)

This manual is about a new approach to design, construction, and facility management called building information modelling (BIM). It provides an insight into BIM technologies, the business and organizational issues associated with its implementation, and the effects that proper use of BIM can provide to all members of a project team. Building Information Modelling (BIM) is one of the most promising developments in the architecture, engineering and construction (AEC) industries. Although the concepts, approaches and methodologies that we now identify as BIM can be dated back nearly thirty years, it is first now that BIM is beginning to change the way we plan, design and construct buildings and other infrastructure.

With BIM technology, an accurate virtual model of a building is digitally constructed. When completed, the computer-generated model contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building. BIM also accommodates many of the functions needed to model the lifecycle of a building, providing the basis for new construction capabilities and changes in the roles and relationships among a project team. BIM therefore facilitates an integrated design and construction process that should result in better quality buildings at lower cost and reduced project duration.

The main objective of this manual on BIM, is to introduce to construction managers the key terms and ideas associated with the implementation of BIM, which may relate to the course of their work or study. In particular, the aim is to provide information and guidance on how they can adopt and implement BIM in their future or current construction projects and company environment.

In this handbook the term 'BIM' refers to an activity (meaning building information modelling), rather than an object (building information model). The intention is to reflect that BIM is not a thing or a type of software but a human activity that ultimately will involve broad process changes in construction.

The handbook contains 6 chapters. Chapter 2 presents definitions of BIM and its comparison with other methodologies like Lean Construction, Virtual Design and Construction and Integrated Project Delivery (IPD). Chapter 3 gives information about BIM dimensions and use of BIM in different construction phases, including procurement. Chapter 4 gives detailed information on key aspects for the successful BIM implementation. The implementation of BIM is further discussed in Chapter 5, which explores the key considerations for the successful implementation of Building Information Modelling (BIM), through an appropriate selection of tools and technologies, i.e. the BIM interface. The final chapter then presents three case studies related to the use of BIM techniques in construction projects.

CHAPTER 2

BIM, SCOPE AND DEFINITION (I. B. KJARTANSDÓTTIR, J. T. SNÆBJÖRNSSON)

2.1 INTRODUCTION

Within the construction phase many problems and errors occur due to difficulties in communication, coordination and standardization. This interoperability issue can be aided with the adoption of Building Information Modelling (BIM), which is said to be most likely a technology-led change to deliver the highest impact to the construction sector[1]. The European Construction Industry Federation predicts that the wider adoption of BIM will unlock 15-25% savings to the global infrastructure market by 2025[2]

If BIM adoption across Europe will deliver 10% savings to the construction sector then an additional €130 billion would be generated for the €1.3 trillion market.[3]

The purpose of this manual is to introduce and explain the role and possibilities of BIM, for the construction manager. It aims to demonstrate how BIM can aid the construction process and how projects, people and organizations can benefit from applying a BIM methodology. The focus is on what BIM is and the benefits that can be expected when implementing BIM in the construction phase.

[1] (ref. World Economic Forum WEF, Shaping the Future of Construction, 2016 http://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_Inspiring_Innovators_redefine_the_industry_2017.pdf)
[2] (ref. BCG, Digital in Engineering and Construction, 2016; McKinsey, Construction Productivity, 2017)
[3] (ref FIEC, Annual Report, 2017)

The main objective of BIM is to enhance project performance and produce better outcomes. BIM helps the construction manager to gather data and information from the relevant disciplines and communicate them more effectively. Here, insights will be given on what BIM is, how it can aid the construction process, what are the pitfalls and how to avoid them, and how the construction manager should apply BIM in the construction phase. The focus is on the construction phase and the construction manager. The manual gives a framework for the implementation, development and use of BIM to facilitate an effective production.

2.2 BUILDING INFORMATION MODELLING (BIM)

BIM means different things to different professionals. Some say BIM is a software application, others say it is a process for designing and documenting information on buildings. Some say it is a holistic approach to design, construction and maintenance a building.

As Figure 2.1 indicates, BIM is many things and most likely, the construction industry has not yet realized its full capabilities. BIM is intertwined with technology, both hardware and software. As the technology evolves rapidly, BIM will also continue to evolve.

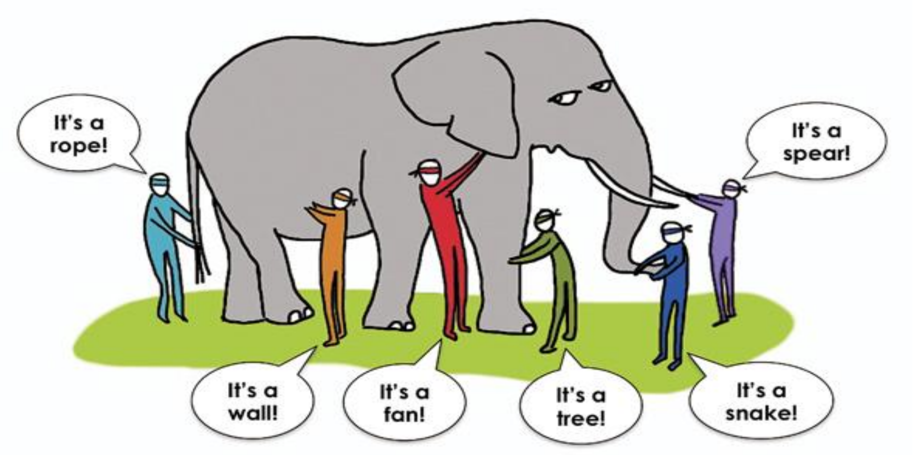

Figure 2.1. BIM can mean different things to different professionals.[4]

[4] https://www.thenbs.com/knowledge/bim-for-all-dummies-or-not

Architectural, engineering and construction (AEC) professionals as well as researchers, have a number of views on what BIM is:

"A modelling technology and associated set of processes to produce, communicate and analyse building models." (Eastman et al., 2008)

BuildingSMART International[5], a not for profit organization supporting open BIM, defines BIM as:

"A new approach to being able to describe and display the information required for the design, construction and operation of constructed facilities."

While there are different definitions of BIM, there is a common consensus that BIM is a Process for combining information and technology to create a digital representation of a project. It Integrates data from many sources and evolves in parallel with the real project across its entire timeline, including design, construction, and in-use operational information.[6]

The term 'Building' within Building Information Modelling can be misleading. Rather than just referring to Buildings, the term should be thought of as the verb to build. The methodology can be applied to all types of construction projects, both vertical and linear including infrastructure projects and land surveying.

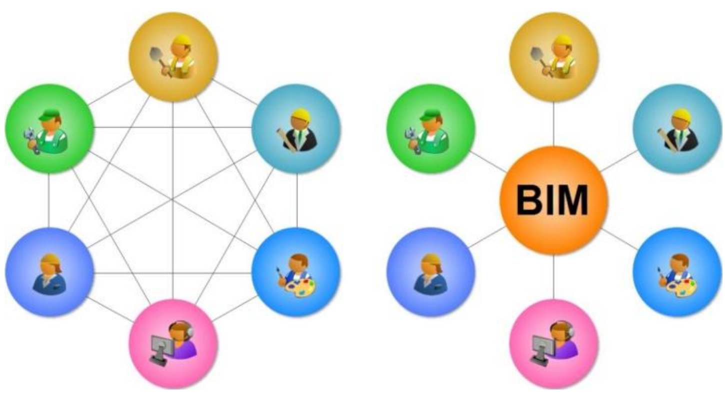

Figure 2.2. Traditional process versus BIM process.

[5] Charter for the National Building Information Model (BIM), Standard Project of the buildingSMART alliance, 2008.
[6] Mordue S, Swaddle P, Philp D, Building Information Modelling for Dummies (Wiley) 2015

In this manual, as generally within the AEC sector today, BIM is regarded as a process focused on the development, use and transfer of digital information in a building or infrastructure projects, aiming at improving design, construction and the operation phase of such facilities.

The real value of BIM lies in the "I" of BIM, i.e. the information that is gathered, integrated into the process and shared transparently between all parties involved. Information is possibly the most important construction "material". The sector needs to have access to the right information at the right time throughout the lifecycle of an asset.

Within the construction phase, many problems and errors occur due to shortcomings within the design phase. Difficulties and restrictions in communication, coordination and standardization are among the problems facing the industry. Communicating design information effectively, plays a big role in overcoming these interoperability issues. This is where BIM can play an important role. In a traditional process documents and drawings are communicated between projects stakeholders, making a new file each time the file is shared. In BIM, the model serves as a database, where information are supplied and pulled out on demand, as figure 2.2 depicts.

2.3 WHY IS BIM IMPORTANT TO CONSTRUCTION MANAGERS?

BIM is most associated with the design team. Construction managers (CM) may not usually be involved in model authoring but they do play a vital role in making sure the key elements needed to deliver a successful project are present and correct. Construction managers need to understand the processes and tools that are used throughout a project's lifecycle, beyond the design phase.

There is a need to manage the asset from inception through to operation and end of life. Construction managers need to understand, interrogate, contribute and validate BIM data, to maximise its benefits. They need to harness the value of data by using model information and new ways of working to better support new construction techniques, scheduling, cost, quality, coordination, fabrication, sequencing and facilities management to name but a few. To be able to tackle this expanded role of the construction manager he needs to consider new tools, processes and skillsets.

2.4 COLLABORATION, THE HEART OF THE BIM PROCESS

At the heart of a BIM process is collaboration. Working as a collaborative team requires the development of better and more efficient ways of working to achieve shared goals. It brings about many advantages for the construction industry, such as improved communication and understanding, leading to greater productivity, quality and cost certainty. Ultimately collaboration results in better outcomes. Creating the right environment for a collaborative workflow requires consideration of Culture and behaviour, Process, Digital tools and the right forms of contracts.[7]

A key success of collaboration hinges on the ability to communicate, exchange, update and use data between different project teams. This requires data to be interoperable. Essentially 'Interoperability' is the software's ability to exchange and make use of BIM data. While different software from the same vendor may be able to 'talk' to each other, across a BIM project, a number of software solutions required making Interoperability becomes a key consideration. In other industries, interoperability is taken for granted. The success of the Internet wouldn't be as great had it not been for its development on open–non-proprietary standards. This allows for devices, services and applications to work together across a wide and dispersed network of networks.

2.5 BUILDINGSMART

Within construction, buildingSMART[8] is the 'worldwide authority driving the transformation of the built asset economy through creation and adoption of open, international standards'. buildingSMART provide the construction industry with a common language that defines how information is communicated.

The buildingSMART alliance has divided BIM into three key elements, often referred to as the BIM triangle[9] (see Fig. 2.3). Each of the three elements are

[7] Mordue S, Swaddle P, Philp D, Building Information Modelling for Dummies (Wiley) 2015

[8] http://www.buildingsmart-tech.org/

[9] http://www.buildingsmart-tech.org/

supported by an international standard which cover terminology, process and data.

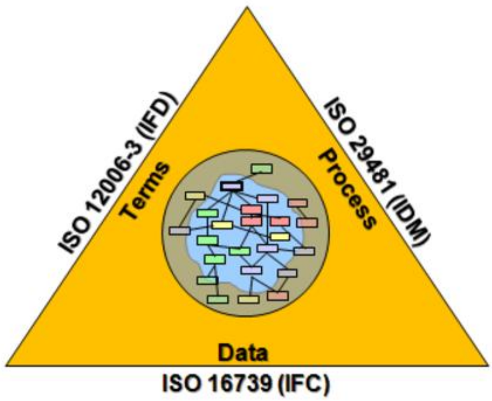

Figure 2.3. BIM triangle (Source: www.buildingsmart-tech.org)

Table 2.1 buildingSMART methodology

Elements for integration and communication of information	**Purpose**
Industry Foundation Classes (IFC)	The rules for exchanging data
Information Delivery Manual (IDM)	The process of exchanging data
International Framework for Dictionaries (IFD)	The mapping of common term
BIM Collaboration Format (BCF)	The changing of coordinates
Model View Definitions (MVD)	Translates processes into technical requirements

These key elements must be in place, in order to use BIM in practice, and be built upon an open, international standards and specifications. Once those three elements are in place (see fig. 2.3), they can be used to engage in "smart building", from which the concept and term buildingSMART is derived. When used together they allow for the effective integration and communication of information. Two further supporting tools including definitions of specific views of information for specific purposes and an open file format to support workflow communications in BIM, processes are provided. These are illustrated in table 2.1 and discussed in more detail in chapter 5. More about buildingSMART can be found from the website http://www.buildingsmart-tech.org/.

2.6 BIM IS A PROCESS DRIVEN WAY OF WORKING

This section addresses the importance of technology agonistic workflows and data exchanges or Open BIM.

The Open BIM approach is more than just 'IFC'. It is a commitment to open standards and engagement. Open BIM is described as a 'universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows.' It is an initiative of buildingSMART and several leading software vendors using the open buildingSMART Data Model.

It allows the construction industry to choose the 'best of breed' software solutions that are right for them. This approach makes it possible for both small and large software vendors the ability to compete. Table 2.2 below illustrates some of the benefits of using agnostic workflows and data exchanges.

Table 2.2 The benefits and consequences of using Open BIM.

Benefit	**Result**
Supports transparent, open workflows	Allows all project members to participate and contribute regardless of software tool
Creates a common language for processes	Allows industry and government to procure projects with transparent commercial engagement, comparable service evaluation and assured data quality.
Provides enduring project data for use throughout the asset life-cycle,	Avoids multiple input of the same data and consequential errors.
Supports 'best-of-breed' solutions	Small and large (platform) software vendors can participate and compete on system-independent,
Energizes the online product supply side with more exact user demand searches	Delivers the product data directly into the BIM.

2.7 COMMON MISUNDERSTANDINGS REGARDING BIM

These three elements, IFC, IDM and BsDD are vital for any BIM project. If a software is able to create a 3D model, but cannot export to IFC file format the value of the data can not always be used by others. If the data created within the project, is not shared and communicated effectively throughout the project's lifecycle, you are not working in a BIM project. The IFC file format allows the industry to share data and information between various software and thereby minimize the interoperability issues within the sector.

Some also regard BIM as just the process of gathering information, however, the process or the information cannot stand alone, without the information model or the buildingSMART data dictionary (BsDD).

A common misunderstanding is to assume that when information models are created, drawings are not needed. At present the model is often shared for information purposes with drawings being an output of the model forming contractual documentation. Drawings are the only thing a construction worker has to rely upon in the field to guide them through the construction. It is certainly possible to extract numerous information from an information model, to provide guidance for the construction worker, but that requires software, hardware and skills. The future may provide the construction industry with technology that will render drawings redundant at the construction site, but today, traditional drawings on paper or in a tablet are required.

It is also a common misunderstanding that BIM is the philosopher's stone, and when implemented it can do magic. BIM works because people make it work. Behind every successful BIM project there are skilled people, with the right tools (software and hardware), that create 3D models, undertake clash detections, 4D schedules and other types of BIM uses. People define and organize BIM outputs. No software can replace that.

There is not any *one size fits all* BIM procurement, when BIM is implemented. There are steps to be taken, decisions to be made and risks to be assessed. Construction projects haven only one thing in common. They are unique, and therefore it is crucial to evaluate each one of them to discover where the risk lie and where problems are likely to occur. Then it is possible to define how BIM can aid in minimising or mitigating those risks and problems for added value of the project.

BIM software can be expensive. Learning new skills and undertaking training can be time consuming and costly. It is difficult to acquire BIM skilled staff, with experience in construction. BIM therefore has to be regarded as an investment, not a cost. It has to be supported top-down with the focus on aiding the construction process.

2.8 INFORMATION MODELS

A BIM model may be thought of as an 'information model', a rich source of data containing graphical, non-graphical and linked documents. The model is progressively developed over the course of the project lifecycle. Typically a model will go through a number of iterations. Firstly as a design intent model or Project Information Model (PIM) which is developed during the design phase. This model is then developed into a virtual construction model typically when the ownership is passed from the design team to the construction suppliers. Finally the Asset Information Model (AIM) is developed for use within the operation and in-use phases.

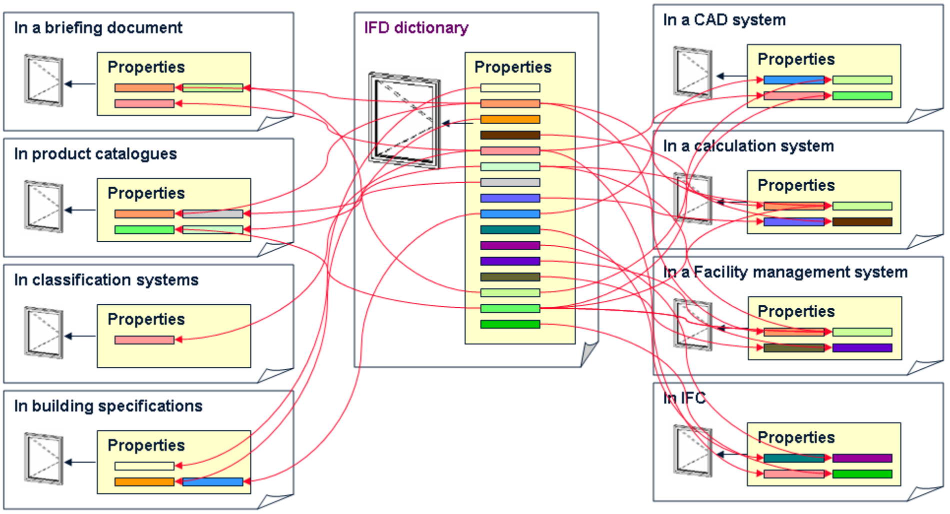

Figure 2.4. Physical and functional characteristics of a window (Source: NBIMS).

Information models are an object oriented design, consisting of elements or objects which have physical and functional characteristics attached to them as well as relation to nearby objects and spaces. An example of an object is a window, as shown in Figure 2.4).

These objects contain graphical and non-graphical information, which enable different kinds of analysis to be performed, such as such as quantifying the material required, as demonstrated in Figure 2.5.

Information model of a single facility can consist of a one model file, or multiple model files where each separate domain model (architect, structural, civil etc.) are brought or federated together in the Common Data Environment (CDE) to present the single model of the asset. Each discipline is still responsible for their model and data.

It is important to realize that BIM is different from CAD (Computer Aided Design). Without proper training, chances are that users will try to force BIM to work as their CAD system did. It is essential to set time aside to determine the purpose of the model, as it dictates the amount of graphical and non-graphical information required as well as the available output. In this context, the old phrase "*Garbage in* - *Garbage out*" should be kept in mind.

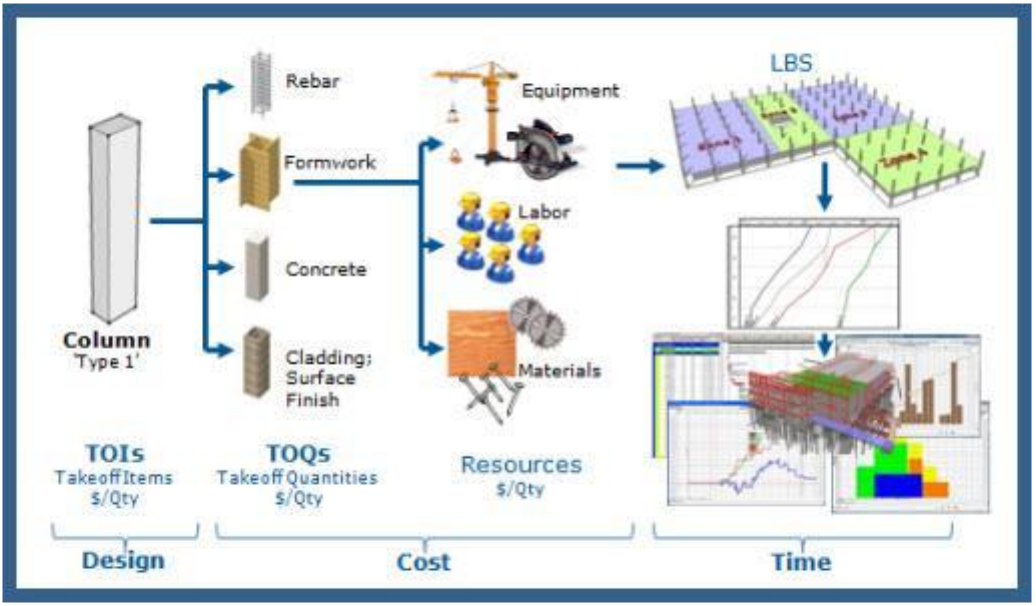

Figure 2.5. Calculations built on an object-oriented design (source: Vico office[10]).

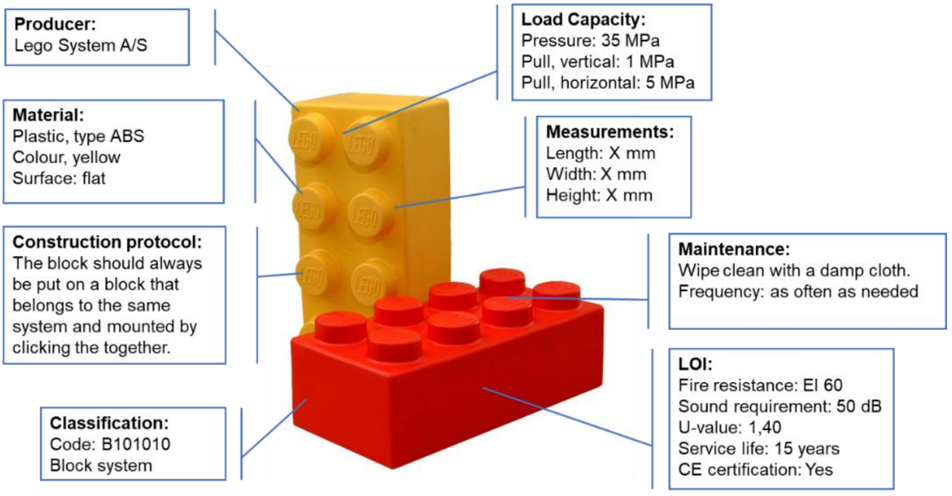

Figure 2.6. The BIM building blocks

[10] http://www.vicosoftware.com/trimble-buildings/vico-office-integrated-3D-4D-5D-BIM-for-Construction

The information model becomes an integral part of the decision-making process throughout the design, construction and management of the asset. To deliver this information and data, a clear strategy is applied together with a a BIM process. The goal is to maximize the return on investment by defining a fluid flow of data use throughout the whole project life cycle. The client will get a more complete information, resulting in improved quality, efficiency and sustainable buildings. Within the BIM process, an information model is produced using BIM supported software. The model can be viewed and manipulated in 3D. Added to that is clash detection software, that detects clashes between and within individual construction parts, such as between utilities and structural elements. This achieves reduction in total operation cost, through improved design and therefore less modifications or clashes at the construction site. Making the constructed facilities, more reliable, maintainable and accessible.

Furthermore, the information model can be linked to scheduling software, enabling a better communication between contractors and other project participants. The project schedule becomes more reliable and the workflow more visual, which again makes the supply management of materials, equipment and workers more effective.

2.9 BIM PROCESS

The information Delivery Cycle provides a logical framework for the production of pertinent information at discrete stages of the whole building lifecycle. The decision to build, extend, demolish or refurbish will be as a result of a response to identified need. This in turn leads to a client brief and client clearly communicating to the supply chain their information needs.

The client is responsible for supplying different types of information requirements related to the delivery or operational phase of an asset. This information can vary, depending on what is of value to the client. These requirements should be expressed in such a way that they can be incorporated into project-related appointments or instructions and passed along to the designers, engineers, contractors and suppliers.

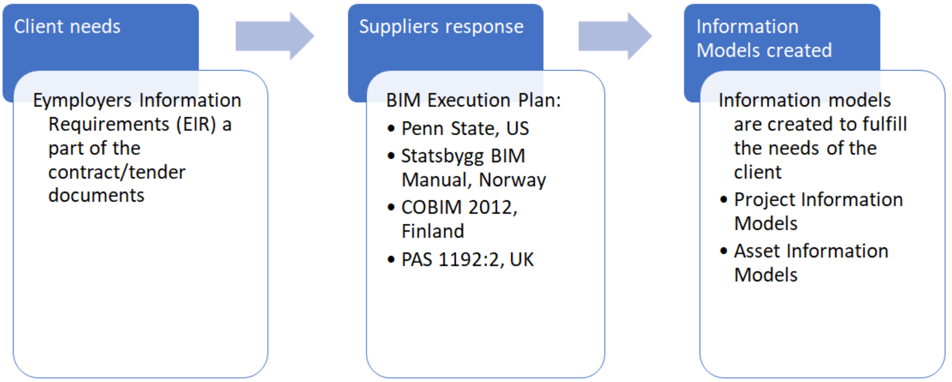

Figure 2.7. Collaborative BIM workflow.

The Employer's Information requirements (EIR) sets out the information to be delivered across the project lifecycle. Within the EIR, the specific information requirements should be aligned to the project stages and each referenced to the needs of the client at each stage. It is likely that there will be multiple EIR on a project, with the contractor's supply chain responding to a contractor-led EIR which will have different information needs.

The EU BIM Task Group has published a handbook for the public sector where the content of EIR is divided into three areas:

- Technical: Details of software platforms, definitions of levels of detail etc.
- Management: Details of management processes to be adopted in connection with BIM on a project
- Commercial: Details of BIM Model deliverables, timing of data exchange and definitions of information purposes

The 'Handbook for the introduction of Building Information Modelling by the European Public sector' is available to download from the EU BIM website (www.eubim.eu).

2.10 BIM EXECUTION PLAN (BEP)

When implementing BIM in a project, the project team should, as soon as possible, plan how BIM is to be executed. Penn State University (PSU) has developed as BIM Project Execution Planning Procedure (BEP), to guide the project team on how to implement BIM and can be downloaded at http://bim.psu.edu/Project/resources/download_thank_you.aspx.

The Guide Provides a structured procedure to follow when creating a BEP. Each construction project is unique, and therefore one-size-fits-all does not apply here.

A BEP has four steps:

1) Identify high value BIM uses during project planning, design, construction and operational phases

2) Design the BIM execution process by creating process maps

3) Define the BIM deliverables in the form of information exchanges

4) Develop the infrastructure in the form of contracts, communication procedures, technology and quality control to support the implementation

The goal for developing this structured procedure is to stimulate planning and direct communication by the project team during the early phases of a project. The team leading the planning process should include members from all the organizations with a significant role in the project. Since there is no single best method for BIM implementation on every project, each team must effectively design a tailored execution strategy by understanding the project goals, the project characteristics, and the capabilities of the team members.

The BIM Project Execution Planning Guide is a product of the BIM Project Execution Planning buildingSMART alliance™ (bSa) Project. The bSa is charged with developing the National Building Information Modeling Standard™ (NBIMS) in USA. This Guide was developed to provide a practical manual that can be used by project teams to design their BIM strategy and develop a BIM Project Execution Plan. The core modelling and information exchange concepts have been designed to complement the long-term goals of the bSa in the development of a standard that can be implemented throughout the AECOO Industry to improve the efficiency and effectiveness of BIM implementation on projects.

Step 1: Identify BIM Goals and Uses

In this step, the value of BIM on the project and for the project team members are clearly defined, by defining measurable goals for BIM implementation. These goals should be linked to project performance and relate to the team's capabilities. When the goals have been defined, specific BIM uses can be identified, to aid these goals.

Step 2: Design the BIM Execution Process

In this step, the BIM process is mapped. High level map showing the sequencing and interaction between BIM uses applied in the project, so the team members understands how their work processes interact with the processes performed by other parties. For each BIM use, the responsible team member designs a detailed process map, for example a map of clash detection.

Step 3: Develop Information Exchanges

Next step is to define the information exchange between team members. Here the goal is to define what the author of the information is to deliver and what the receiver can expect to receive. In this step, a level of development is defined for each use, and for each phase of the project.

Step 4: Define Supporting Infrastructure for BIM Implementation

At this stage, the necessary items and functions of the project have been identified. In this step the necessary infrastructure is defined, which should address software, hardware, quality control procedures, contract language, co-ordinates, naming procedures, FTP servers, project viewer etc.

2.11 BIM MATURITY LEVELS

BIM maturity levels are used to describe the maturity a BIM project. They are useful in that they identify what the supply chain is expected to deliver, while the client can clearly understand what the supply chain is offering.

There is some debate within the industry about the exact meaning of each BIM level. In this chapter, the broad concept is described.

Level 0: PRE BIM

This stage is the starting point, the status before the implementation of BIM, and means no collaboration between project team and is defined as unmanaged CAD.

2D documentation is most likely used to share information. Though 3D visualizations can be used, 2D is the basis for all documents. quantities, cost estimates and specifications are generally not linked to the visualizations model or documentation. In this stage, there is no digital collaboration. The output is paper drawings or electronic prints, or mixture of both.

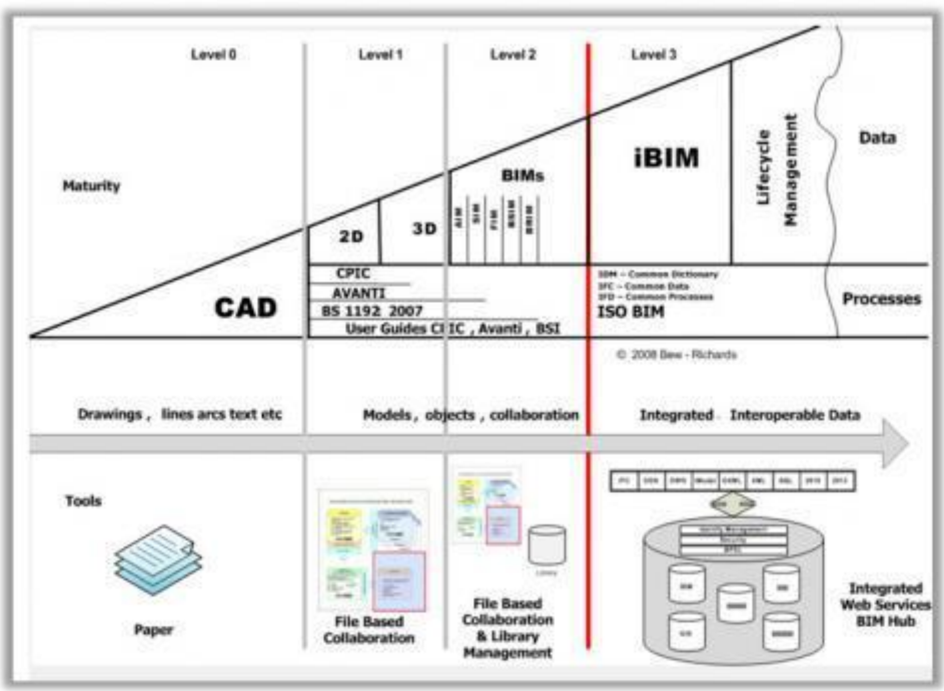

Figure 2.8. UK's BIS-BIM Strategy[11]

[11] http://www.bimtaskgroup.org/wp-content/uploads/2012/03/BIS-BIM-strategy-

Level 1: Object based modelling

Object-based 3D parametric software tool is used to produce models. Users produce models within all stages of a construction, and the model is the basis for 2D documentation and 3D visualization.

The difference between stage 0 and 1 are minor process changes and contractual relations. Typically, in stage 1 a mixture of 3D CAD, for concept work, and 2D CAD for documentation and product information. Electronic sharing of data is carried out from a common data environment, often managed by the contractor. Collaboration between different disciplines does not occur.

Level 2: Collaborative BIM

In this stage, different disciplines are actively cooperating with others through a model based collaboration process. The collaboration often occurs through a cloud based application. Contractual amendments become necessary and models can be linked to various analysis tools. Processes are assessed through the models.

Each discipline is building up their own model, instead of single shared model. The collaboration appears through information exchange between disciplines, which becomes the crucial aspect of this level. Design information is shared through a common file format (such as IFC and BCF), within a Common Data Environment (CDE). This enables organisations to combine data with their own model and use the information onwards.

Level 3: Integrated BIM (iBIM)

In this level, semantically-rich network based integrated models are created, shared and maintained collaboratively through the project life-cycle phases. Models in this stage become interdisciplinary nD models, where complex analyses at early stages of design and construction are allowed. Model deliverables include business intelligence, lean construction principles, green policies and whole life-cycle costing. The Project Lifecycle is now phase-less. In this stage, major changes are necessary on contractual relationships, risk-allocation models and procedural flows. A shared interdisciplinary model is necessary to provide two-way access to project stakeholders, which will eventually facilitate into Integrated Project Delivery (IPD) The precise details and aspects of Level 3 are yet to be defined, but are likely to be centred around open standards and will require new legal frameworks.

2.12 BENEFITS OF BIM

BIM can provide numerous benefits to a project, when implemented properly and can be applied either at all phases of a construction project, or just one of them. It can for instance result in improved design quality through:

- Effective analysis cycles,
- Effective prefabrication due to better information and more predictable field conditions,
- Efficiency on site due to enhanced visualization of the planned construction schedule,
- Innovation in using digital design applications.

The following list presents some of the benefits that BIM offers to the AEC sector, such as the design team, the construction team, the facility manager, etc. BIM can provide:

- Reliable, accessible electronic information over the life cycle of the structure
- Design documentation with increased accuracy and improved quality
- Better production value
- Enhanced basis for decision making
- Overview of changes during design and construction
- Fewer changes in supply orders
- Shorter construction time
- Reduction in errors and omissions
- Improved operation and maintenance
- Better total cost of ownership

BIM offers a more efficient way of doing various analysis required during the building process, which all aid the decision making and supervision process, and improves the odds that the anticipated construction will be carried out. BIM is the tool that enables the construction manager to pull out the information required when it is needed. An example of such analysis are:

- Accurate quantification of supplies needed can easily be evaluated within the model
- Cost analysis throughout all phases of the project can be provided in less time
- Better visualisation of the project, throughout all phases.
- Constructability analysis are easier to perform.

By virtually building the project, prior to physically constructing it, the contractor is able to analyse the design, sequence and explore the project through a digital environment. It is far less expensive to make changes in the digital environment, than in the field during construction, where changes are exponentially more costly.

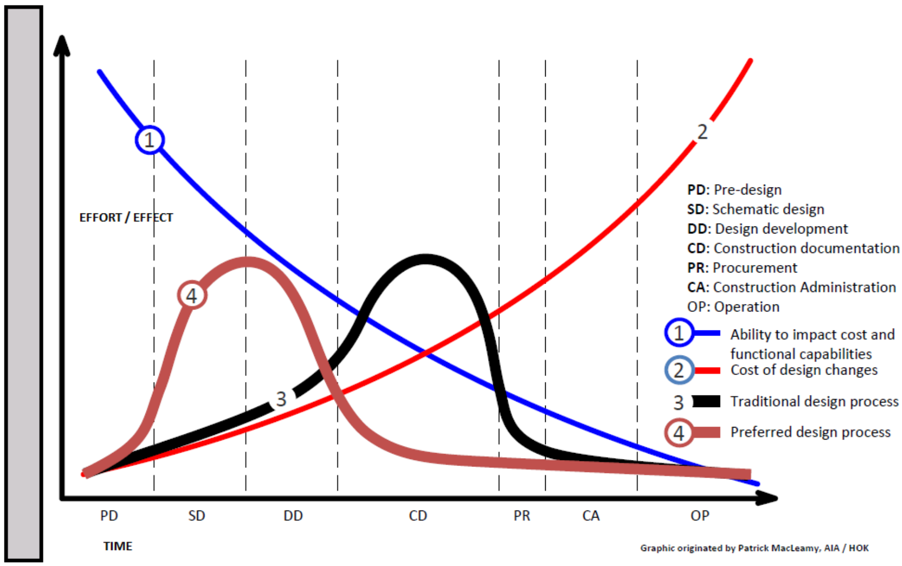

Figure 2.9. MacLeamy curve, BIM workflow versus traditional process [12]

When planning and building a BIM, the design team is more likely to accumulate and analyse a better quality information as shown in figure 2.9. Let´s look at cost analysis for an example. A BIM model consist of objects in an object oriented design, which makes it easier to get more accurate information on the variables within the model. When the design changes, or decisions have to be made on which material is to be used, the available BIM makes it easy to see how the cost will be affected by the use of different materials. Therefore changes are more likely to occur in the design phase, rather the construction phase, at which point all design changes involve added cost.

Design intent is also easier to communicate to the client through all sorts of 3D views, videos and even augmented reality. That way, the client has a better understanding of the project, and is more likely to comment on or require

[12] Patrick MacLeamy, AIA/ HOK

changes earlier, resulting in a product, the building, that meets the client needs at lower cost. As we all know, it is more expensive to move a wall during the construction phase, than moving an object in a model.

Figure 2.10. BIM on the construction site [13]

Another aspect of how BIM aids the construction manager, is the visual aid and ease of getting information on site. On a typical construction site, there can be many different languages spoken. Normally 2D drawings are used to communicate design intent, but a 3D model provides a better visualisation for everybody. Today it is possible to have apps on an iPad, smartphone or tablets to access the model and drawings on location at the building site. This is more effective and convenient than looking through many different A1 drawings in the worksheet to check if an installation can be repositioned.

2.13 OTHER METHODOLOGIES

The construction industry is often known for being a low-tech industry, which can be inefficient and wasteful. Information technology, through BIM, has the potential to aid the sector, by making the construction process more transparent. It aids understanding, changing the way things are built, streamlining processes and minimizing waste. BIM alone will not do all this, but it does provide the industry with the tools to aid the construction processes.

[13] http://www.skanska.co.uk/about-skanska/innovation-and-digital-engineering/digital-engineering-and-bim/the-expertise-of-our-people/

In this section, other methodologies will be presented and how BIM affects them. First, the synergies between Lean Construction are reviewed and then a rather new terminology, Virtual Design and Construction (VDC), is introduced.

2.13.1 Synergies between Lean Construction, BIM and Integrated Project Delivery

BIM is no longer a new trend and there are stakeholders who have understood the benefits BIM promises. Those benefits, value maximization and waste reduction, are in line with the benefits lean construction promises. Whether or not lean construction practices are desired, the outcome is similar. BIM applications actually enable the full effect of lean principles. By using BIM, all processes become leaner, waste has been reduced and value increased. When BIM and lean construction principles are used together the construction process can become even more enhanced, as the project team becomes more able to tackle complex dynamics and challenging target goals related to the delivery of the project. Such as: [14,15]

- Reduce end-product variability
- Reduce production variability
- Reduce production cycle-durations
- Reduce batch-sizes towards single piece flow
- Use pull systems
- Verify and validate value generation
- Decide by consensus
- Ensure consistency of requirements
- Standardize work processes
- Visualize production process

Waste elimination

By integrating information, using BIM, rework of drawings and documentation is reduced, resulting in improved communication between stakeholders and better quality of drawings and documentation. Waste is reduced in the design process and on site. By tying design information to cost estimate, budget and schedule, manual work is avoided and the information of the management system is synchronized at all times.

[14] http://leanconstructionblog.com/Top-Ten-Synergies-between-Lean-Construction-and-BIM.html
[15] http://ascelibrary.org/doi/pdf/10.1061/(ASCE)CO.1943-7862.0000203

Specification of value from the perspective of end-user or customer

Virtual reality is used to describe the facility to be built. The client sees what he is about to buy, and is able to criticise if he is not satisfied. Furthermore, it is easier to explain the reasons for why the design is the way it is.

Identification of the process delivering what the customer values (the value stream) and eliminating all non-value adding steps

The high level of visualizations in BIM enabled project team to simultaneously explore both product and process design. Virtual reality describes the construction process, aiding the value stream to be identified, stimulating waste reduction and reducing non value-adding steps.

Make the remaining value adding steps flow without interruptions by managing the interfaces between different steps

To have the ability, to proactively change daily tasks assignments in close coordination with all parties makes it easier to manage the flow. By visualizing workflow in control systems enables deeper collaboration between teams on and off site. 4D scheduling helps identify bottlenecks and improve flow.

Let the customer pull - do not make anything until it is needed, then make it quickly

Because of the integration of the model, information can easily be pulled from the model at any time, with updates on design changes, cost, and time. The better integration of information should reduce errors. Pull effect is achieved and reduced variability within the construction process.

Continuous improvements

A work schedule, linked to BIM, plans the process. Then they are procured and what happens is described and measured, i.e. with constructability reports given to architects and engineers. In future projects, mistakes identified are most likely not repeated.

Transparency

BIM-based visualization interfaces are important tools for providing process transparency. Virtual construction and high level of project visualization held develop a common understanding among project partners. Lean construction stresses the need for a better co-operation between stakeholders at the early stages of a project. By facilitating a cross functional team, maximum value can be generated for the project stakeholders. For a transparent process, communication and data sharing is important. A BIM process pulls the project team together and enables them to communicate and share data effectively. A transparent process is also established when a field system is linked to BIM software, resulting in continuous information flow between project stakeholders.

Although lean principles and BIM do not rely on each other, there is a strong synergy between them. BIM applications enable the full effect of lean principles. Effective BIM is about the process, and lean is an operating system for implementing new processes and tools. When BIM is fully integrated within organisations, IPD is reached, the processes become leaner, waste has been reduced and value has been increased. The value of BIM can be enhanced even more if used with lean principles. These two approaches aim at the same objectives, reduce waste and increase value.

2.13.2 Virtual design and construction (VDC)

Virtual Design and Construction (VDC) is the use of integrated multi-disciplinary performance models (BIM models) of design-construction projects to support explicit and public business objectives. *"At its core, VDC ultimately seeks to bridge the expertise gaps between design, construction, and operations; to realize facilities that are dramatically less wasteful both in assembly and usage; and to create buildings that function to serve their occupants throughout the complete usage lifecycle."* [16]

The main difference between BIM and VDC is that in BIM the output is a information model(s), but in VDC the input is a information model(s). VDC focuses on the design and construction processes, where the objective of a VDC output, is to aid the design and construction process.

VDC models are regarded as performance models, in the sense that they predict some aspects of project performance, track many that are relevant and can show predicted and measured performance in relationship to stated project objectives.[17]

[16] L. Anderson et al, 2016

[17] "CIFE Mission Statement" CIFE website, retrieved December 2007

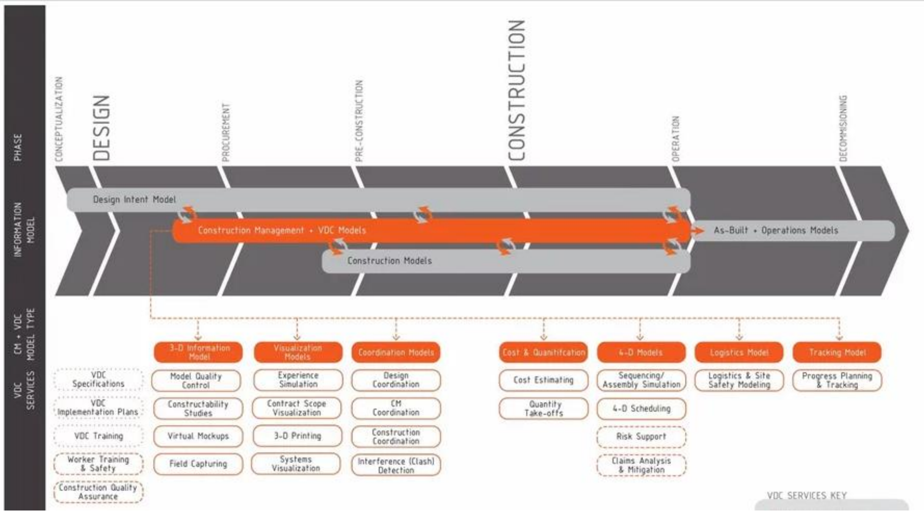

Figure 2.11. VDC Practice Diagram [18]

In VDC, a BIM model is regarded as an information model. VDC focuses on those aspects of a project that can be designed and managed. A VDC process, is a workflow that incorporates the BIM model, that acts as a hub. VDC processes seek to apply new technologies to the industry and link the work done back to the information model. VDC services are specific services unique to VDC, such as clash detection, 3-D scanning or 4D scheduling. A VDC product is the deliverable resulting from a VCD service, such as a point cloud or a database. Whereas the BIM model simulates the geometry and data of an environment. It is a virtual, geometrical, spatial relational database.

Some contractors are applying VDC within their organisation, even though they are not receiving any BIM models from the designers or clients. In these situations, the contractor sees the value in putting the time and effort in modelling the construction and using that data to optimize their own processes and improve business performances by doing so. BIM and VDC are very similar. One could say that BIM uses, as presented in the PSU BEP guide are VDC services. The main difference lies in the standards, where VDC is not defined by buildingSMART Alliance, although VDC projects can certainly apply them.

[18] L. Anderson et al, 2016, p. 8

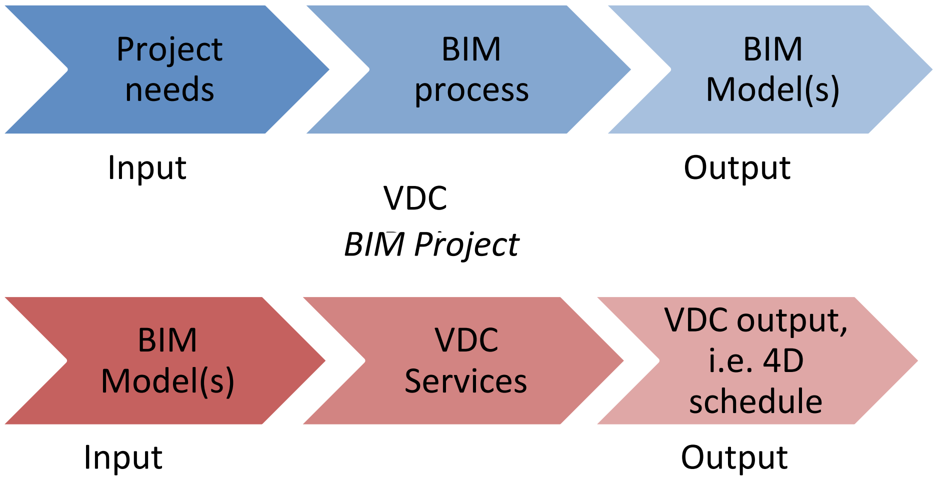

Figure 2.12. BIM project versus VDC project

2.13.3 Integrated Project Delivery (IPD)

IPD represents full collaboration between all disciplines by using a single, shared project model held in a centralized repository. All parties can access and modify that same model, and the benefit is that it removes a layer of risk for conflicting information.

Issues such as copyright and liability are intended to be resolved by robust appointment documents and software originator/read/write permissions, as well as by shared-risk procurement routes such as partnering. Protocols such as the CIC BIM Protocol makes provision for these by way of a simple amendment to existing contracts.

The model created is semantically rich, shared and maintained collaboratively through the project life-cycle phases. Model deliverables include business intelligence, lean construction principles, green policies and whole life-cycle costing.

IPD principles are applied to contractual arrangements and tight collaboration between key participants is required from early design throughout project handover.

The AIA California Council defines Integrated Project Delivery (IPD) as: "A project delivery approach that integrates people, systems business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction." IPD principles are applied to contractual arrangements and IPD teams will usually include members well beyond the basic triad of owner, designer and contractor. Tight collaboration between key participants is required from early design through project handover, as is shown in Figure 2.13. IPD can be delivered without BIM, but to efficiently achieve the collaboration required, BIM is an effective tool.

The collaboration IPD is built on, is best suited to business models that:

- promote early involvement of key participants,
- equitably balance risk and reward,
- have compensation structures that reward "best for project" behaviour,
- clearly define responsibilities without chilling open communication and risk taking,
- implement management and control structures built around team decision making with facilitation, as appropriate.

IPD is defined as the long-term vision of BIM as an amalgamation of domain technologies, processes and policies. This term is used as an attempt to include all pertinent BIM visions irrespective of their originating sources.

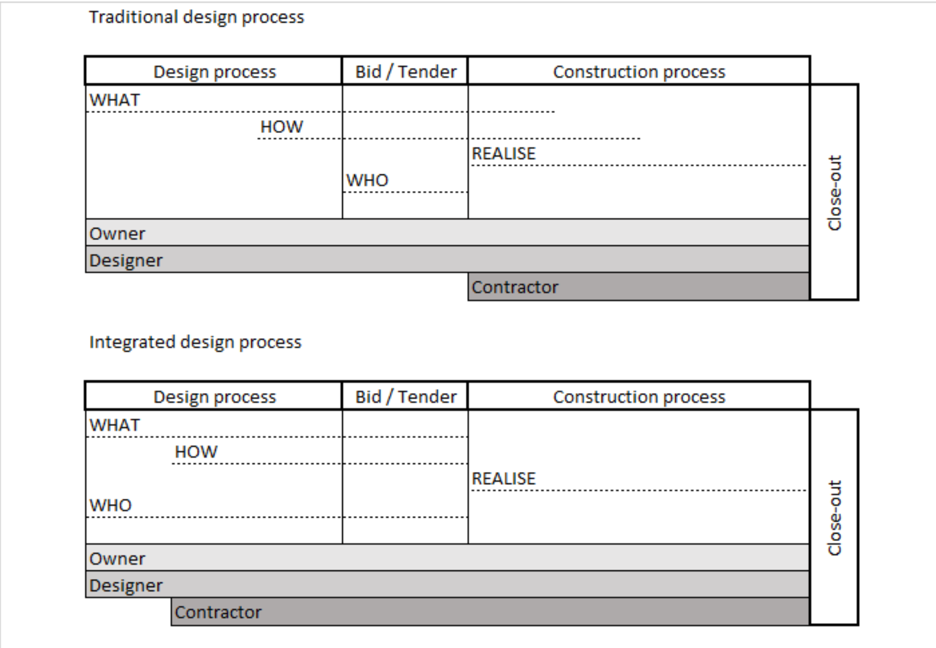

Figure 2.13. Traditional design process vs. IPD design process.

CHAPTER 3

BIM FUNDAMENTALS

(I. B. KJARTANSDÓTTIR, J. T. SNÆBJÖRNSSON)

3.1 BACKGROUND

BIM models are used in various ways in a project, where the aim is to assist and aid the design, construction and operation of a facility. In this chapter the Level of Development and BIM uses are explained. Furthermore, the effect BIM can have on procurement methods and the construction manager are reviewed.

3.2. LEVEL OF DEVELOPMENT (LOD)

An information model combines graphical data, such as geometry and shape, and non-graphical information such as performance requirements and other associated documents. At each stage within the design and construction phase, the objects in the model develops, as needed / stated in the EIR. Level of Definition or Level of Development (LOD) is the term used to describe which graphical and non graphical information the object should contain.

The BIM Execution Plan (BEP) includes detailed information on the LOD required for each given project milestone or specific BIM use, defining who is responsible for producing the information.

Some organisations provide a template for this, based on Uniformat (North America) or Uniclass (UK), which are standards for classifying building specifications, cost estimating and cost analysis. In some modelling software's, these classifications systems are built in or can be added. Other classification systems are available and used in some countries, e.g. Denmark, Finland, Norway. Other organisations and institutions do provide LOD specifications such as BIMForum, AIA, Penn State, Senate Properties (Finland), Statsbygg (Norway), where the LOD is defined for each building element. These specifications are often an appendix to design and/or construction contracts.

When the LOD is defined, it is important to know what is to be produced. One could compare this stage with baking a cake; do I want chocolate cake or carrot cake? If I don't know which one, how can I then define the grocery list? To be able to define the LOD, you need to analyse the project (pick a cake), and define which BIM uses are to be applied in the project, hence 2nd step in the BEP. The next step is to define the LOD, to ensure that the model will contain all the information and geometry that is needed, for every BIM use to be applied in the project. The fundamentals of LOD are discussed in chapter 4.

The LOD definition for the various objects can be different from one project to the next. The LOD definition depends on which BIM uses are to be applied in the project, and what information is needed at projects milestones. When the LOD is defined, there is no "one-size-fits all" solution.

Unfortunately, some project teams choose to skip this step, which generally leads to problems later in the process, resulting in reworking of the model which can be time consuming, wasteful and result in task delay or that a BIM use can't be performed.

3.3. BIM DIMENSIONS

BIM models are often divided into dimension. In a traditional project, information is represented in 2D drawings and text. The geometry in the 2D drawings is described with lines and curves, where the receiver of the information is left to interpret what is missing. Furthermore, the information on what is being drawn is often described in specifications in another document, with no link to the drawing. When changes occur, it is up to team members to remember where to change quantities, text, lines and curves.

In the current BIM literature, there is a growing trend to refer, not to BIM dimensions, but rather to special purpose models based on the five fundamental uses of BIM, which are:

- Model-based coordination
- Model-based scheduling
- Model-based estimating
- Model-based facilities management and
- Model-based analysis

A reference to the direct fundamental use of the BIM model may be more logical than referring to BIM dimensions, which assumes that when creating a model for estimation the 4th dimension needs to be added. In some projects, modelling work is aimed at performing specific analysis, i.e. light analysis or structural analysis.

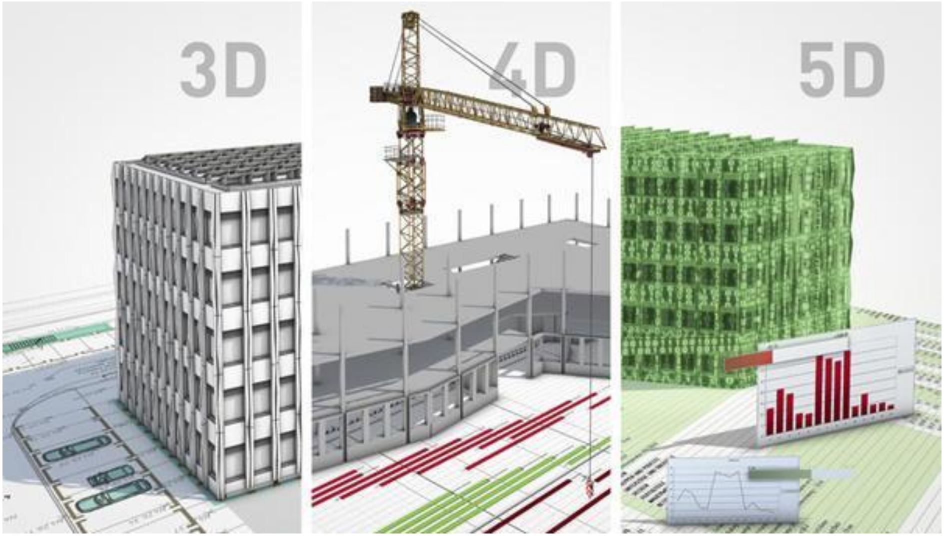

Figure 3.1. Different BIM dimensions [19]

In the following subsections, the BIM dimensions are explained and key benefits pointed out.

3rd Dimension

A 3D BIM model contains 3D objects that builds up the information model. These objects represent the building or buildings spaces, in a virtual reality. These 3D objects contain information, as a minimum, on length, width and height. Other information can be applied, such as material and finish. Key benefits of a 3D information model are improved coordination, enabled visualization and general information gathering. 3D modelling requires 3D modelling software and LOD definition.

[19] http://ndbim.com/index.php/pt/home-pt/bim

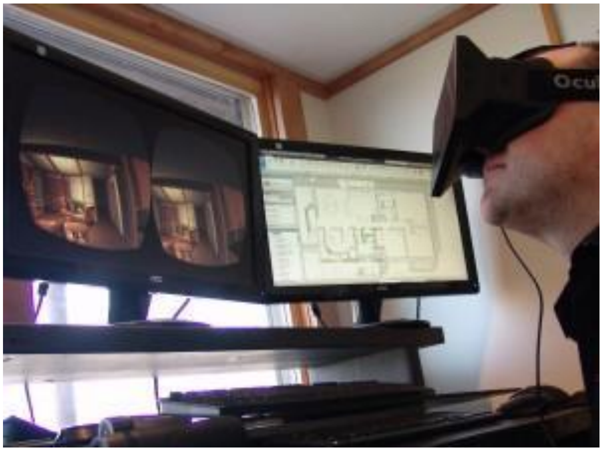

Figure 3.2. A 3D model used for visualisation. [20]

4th Dimension - time

The 4th dimension refers to adding time to the 3D, often called 4D modelling or model-based scheduling. This is done by linking objects from the 3D model, to a task in the construction schedule, using a 4D scheduling tool like Vico Office[21], Synchro[22] or Navisworks[23]. This approach is changing how complex projects are planned, making it possible to visualize the whole construction project or just some phases of it, and see who timing of tasks affect the workflow. This includes comparison of planned versus actual schedules; time-based clashes, such as verifying the planned sequence towards constrained activities (i.e. demolition, permanent construction and temporary construction), site utilization planning and more.

A 4D model can be used at all stages of the project. During the conceptual design, it can be used to discuss site logistics. During the construction phase it can be used to validate costs of completed work, demonstrate work to owners, provide health and safety instructions and justify subcontractor billings to the owner for completed work. Once a 4D schedule is setup, it requires little work to maintain and update.

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[20] http://archvirtual.com/2013/04/15/revit-and-oculus-rift-via-unity3d-experiencing-bim-in-virtual-reality/
[21] http://www.vicosoftware.com/products/Vico-Office
[22] https://www.synchroltd.com/products/synchro-pro/
[23] https://www.autodesk.com/products/navisworks/overview

Figure 3.3. 4D model [24]

4D modelling has become very popular dimension of BIM, due to its ability to give immediate clarity to all stakeholders in understanding the construction activities and space requirements on the building site.

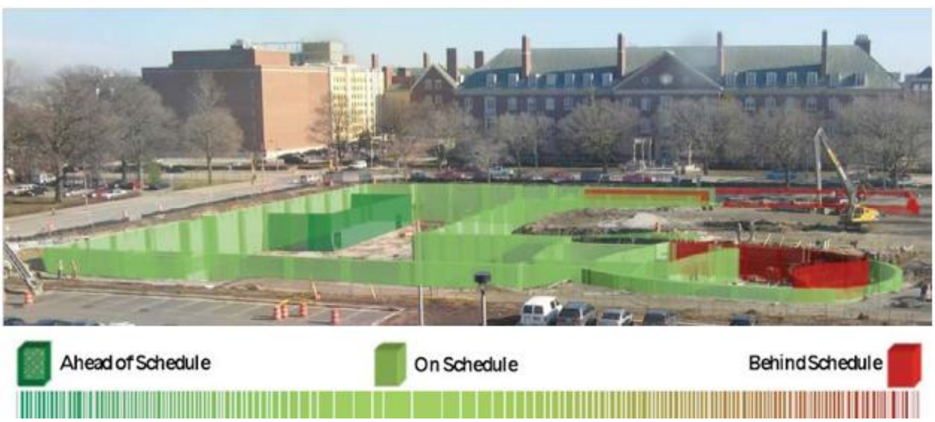

Figure 3.4. 4D model used to compare planned
versus actual construction schedule. [25]

4D modelling can be referred to either as 4D timeline and 4D sequencing. A 4D timeline is the process of linking the 3D objects to the construction schedule and defining time on each object. The output is a virtual animation of the whole construction phase. When done properly, it is possible to control the whole construction site, including labour, equipment and logistics. A 4D sequencing is where 3D objects are arranged in a sequence, the time is not so important in

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[24] https://www.pinnaclecad.com/services/4d-construction-simulation/

[25] https://www.linkedin.com/pulse/integration-between-4d-simulation-mobile-technology-reality-elgohari

this scenario. The goal is to analyse the workflow before work begins on site for better understanding of complications and risk factors.

For 4D modelling to be successful, it is important to integrate skilled persons to the team, that understands construction sequence and scheduling logic as well as which software to use.

5th Dimension - Cost

5D modelling or model-based estimating is the 4D model in addition to cost information. A model-based schedule or 4D schedule is associated with information on cost, which allows the owner to know the exact amount the contractor should be billing at a given time. Over the past years the method has been redefined, where the 5D estimations is done in the form of a take-off, where the model is used to extract quantities of materials and associate costs with those materials for estimating purposes.

It should be noted that the model cannot provide accurate estimates until LOD has been properly defined. Experienced personnel in both technology and in cost estimation are required to achieve success in applying the 5th dimension.

6th Dimension - Facilities Management

The 6th dimension is devoted to Facilities Management and focuses on leveraging the model information to reduce owners' cost over the life cycle of the building or structure. Sometimes 6D BIM models are referred to as Asset Information Models (AIM).

A 6D model does not necessarily contain all the information from previous dimensions. Over the design and construction phase, information for the operation of the facility is gathered. The model should contain information on the colour of a wall, types of doors, frequency of maintenance on the roofing felt, type of light bulbs etc., but size of reinforcing bars is generally not necessary. Time and cost are included, but the objective here is to gather information on frequency of maintenance and analysing the operational cost.

Information for facilities management is often gathered by using an information exchange standard, Construction Operations Building Information Exchange (COBie), developed by National Institute of Building Sciences. The aim is to deliver asset data a distinct entity from geometric information.

Analysis (nD)

Model based analysis or nD modelling refers to information models that are used for various analysis driven by qualitative costs, often related to the tenants/users of the facility, environmental and sustainability issues. These analyses can also be fire safety, acoustics, orientation of the building, with regard to wind direction, heat gain for natural ventilation, daylight analysis or Life-cycle costing (LCC). In these types of models, time and cost is only relevant if the type of analysis requires it.

Model-based analysis enable better and more accurate decision making early on in the design process. Various add-ons to a general 3D modelling software are needed as well as specialized personnel, for nD modelling to be successful.

3.4 BIM USES IN THE CONSTRUCTION PHASE

BIM uses are the actual outputs from the BIM process. Penn State University (PSU) has identified 25 BIM uses, organized by project phase of project development. These BIM uses are available on the BIM Execution Project website. [26]

In this chapter BIM uses within the construction phase are described, as they are presented in the Penn State University guidelines. The key uses are introduced and explained further in the following subsections.

3.4.1 Existing Conditions Modelling or Field Capturing

A 3D model is developed of existing conditions for a site, facilities on site, or a specific area or a space within a facility. The model can be developed in multiple ways; modelling software, laser scanning and other surveying techniques, depending on what the goal is and what is of most value for the project. When laser scanning is used, an extremely accurate 3D point cloud is created which can be linked to the BIM model and used to model the space or validate existing models.

[26] http://bim.psu.edu/Uses/default.aspx

Figure 3.5. 3D laser scanning an information model used to coordinate [27]

Today authoring software is evolving fast, so it is possible to model almost directly from the point cloud, with the use of specialized plugins.

Benefits:

- Enhances efficiency and accuracy of existing conditions documentation
- Provides documentation for future uses
- Aids in future modelling and 3D coordination
- Provides accurate representation of work that should be put in place
- Real-time quantity verification for accounting purposes
- Provides detailed layout information
- Pre-disaster planning
- Post-disaster record
- Use for visualization purposes

Requirements:

- BIM supported modelling software
- Laser scanning point cloud manipulation software

[27] http://haskell.com/Recursos/Octubre-2014/Estudio-de-Caso-El-escaneo-laser-en-3D-y-el-Model

- 3D laser scanning
- Conventional surveying equipment

Personnel skills:

- Ability to manipulate, navigate, and review a 3D model
- Knowledge of Building Information Model authoring tools
- Knowledge of 3D laser scanning tools
- Knowledge of conventional surveying tools and equipment
- Ability to shift through mass quantities of data that is generated by a 3D laser scan
- Ability to determine what level of detail will be required to add "value" to the project
- Ability to generate Building Information Model from 3D laser scan and/or conventional survey data

3.4.2 Cost Estimation or Quantity Take-off

Information models are used to generate accurate quantity take-offs and cost estimates at a faster rate of modelled materials. Here the model is linked to a cost database, which then computes a cost estimate.

Benefits:

- Assist decision making process
- Better visual representation of project and construction elements that must be estimated
- Provide more accurate cost information to the owner during the early decision making phase of design and throughout the lifecycle, including changes during construction
- Reduce time on quantity take-offs and cost estimations
- Allows estimators to focus on more value adding activities in estimating such as: identifying construction assemblies, generating pricing and factoring risks, which are essential for high quality estimates
- Added to a construction schedule (such as a 4D Model), a BIM developed cost estimate can help track budgets throughout construction
- Easier exploration of different design options and concepts within the owner's budget
- Quickly determine costs of specific objects
- Easier to strain new estimators through this highly visual process

Requirements:

- 3D model of the right quality and accuracy
- Model-based estimating software
- Design authoring software
- Cost data, such as Uniformat or Uniclass data
- The estimate will only be as accurate as the LOD of the model.

Skills:

- Ability to define specific design modelling procedures which yield accurate quantity take-off information
- Ability to identify quantities for the appropriate estimating level upfront
- Ability to manipulate models to acquire quantities usable for estimation

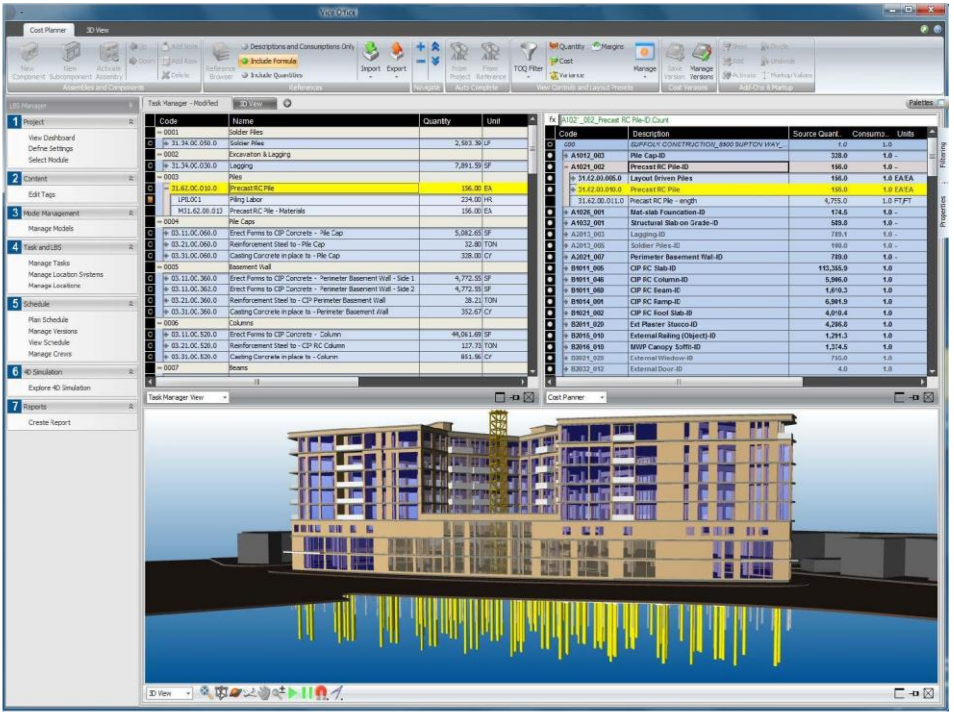

Figure 3.6. 5D modelling in Vico Office. [28]

[28] https://network.aia.org/technologyinarchitecturalpractice/events/new-item

3.4.3 Phase planning

Phase planning is described as the process of a 4D model used to plan the phased occupancy in renovation, addition, retrofit, or to show the construction sequence, and space requirements on a building site. A 4D modelling is a very powerful visualization and communication tool that can give project stakeholders a much better understanding of the project.

Phase planning is used today when selecting winning contracts and communicate how the job would be run. This can include design, staging, phasing, access requirement, scheduling and other qualifications.

Value:

- A better understanding of the phasing schedule for stakeholders which shows the critical path of the project
- Dynamic phasing plans of occupancy offering multiple options and solutions to space conflicts on site
- Integrate planning of human, equipment and material resources with the BIM model to better schedule and cost estimate the project
- Space and workspace conflicts identified and resolved ahead of the construction process
- Marketing purposes and publicity
- Identification of schedule, sequencing or phasing issues
- More readily constructible, operable and maintainable project
- Monitor procurement status of project materials
- Increased productivity and decreased waste on job sites
- Conveying the spatial complexities of the project, planning information, and support conducting additional analyses

Requirements:

- Design Authoring Software
- Scheduling software
- 4D modelling Software

Skills:

- Knowledge of construction scheduling and general construction process. A 4D model is connected to a schedule, and is therefore only as good as the schedule to which it is linked.
- Ability to manipulate, navigate, and review a 3D model.

- Knowledge of 4D software: import geometry, manage links to schedules, produce and control animations, etc

3.4.4 Site Utilization Planning

Information models are used to visualize permanent and temporary facilities on site during multiple phases of the construction process. The model can also be linked with the 4D schedule to convey space and sequencing requirements on site. Furthermore, information on labour resources, materials with associated deliveries and equipment location.

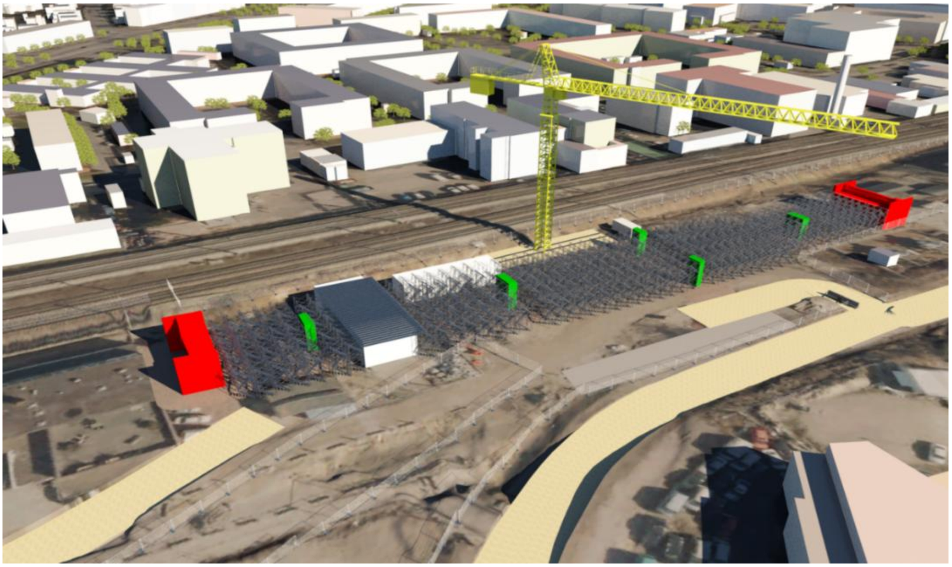

Figure 3.7. Site Utilization planning[29]

Value:

- Efficiently generate site usage layout for temporary facilities, assembly areas, and material deliveries for all phases of construction
- Quickly identify potential and critical space and time conflicts
- Accurately evaluate site layout for safety concerns
- Select a feasible construction scheme

[29] A figure from a project by Per Aarsleff, Denmark

- Effectively communicate construction sequence and layout to all interested parties
- Easily update site organization and space usage as construction progresses
- Minimize the amount of time spent performing site utilization planning

Requirements

- Design authoring software
- Scheduling software
- 4D model integration software
- Detailed existing conditions site plan

Skills:

- Ability to create, manipulate, navigate, and review a 3D Model
- Ability to manipulate and assess construction schedule with a 3D model
- Ability to understand typical construction methods
- Ability to translate field knowledge to a technological process

3.4.5 3D Coordination and Clash detection

Clash detection software is used to coordinate field conflicts by comparing 3D models of building system. The goal here is to eliminate major system conflicts prior to installation. Every system and subsystem is colour coded for ease of visual understanding.

Clash detections are based either on geometry or on rulesets. Geometry-base clash detection detects when two or more objects interfere. Rule-based clash detection detects when for example an object is place before a door, but is not interfering, or when a column is placed on a slab with no footing, of if a space is large enough as it should be, according to building regulations or space requirements from owner. Rule-based clash detection is used for checking the quality of the design.

Value:

- Coordinate building project through a model
- Reduce and eliminate field conflicts; which reduces RFI's significantly compared to other methods
- Visualize construction

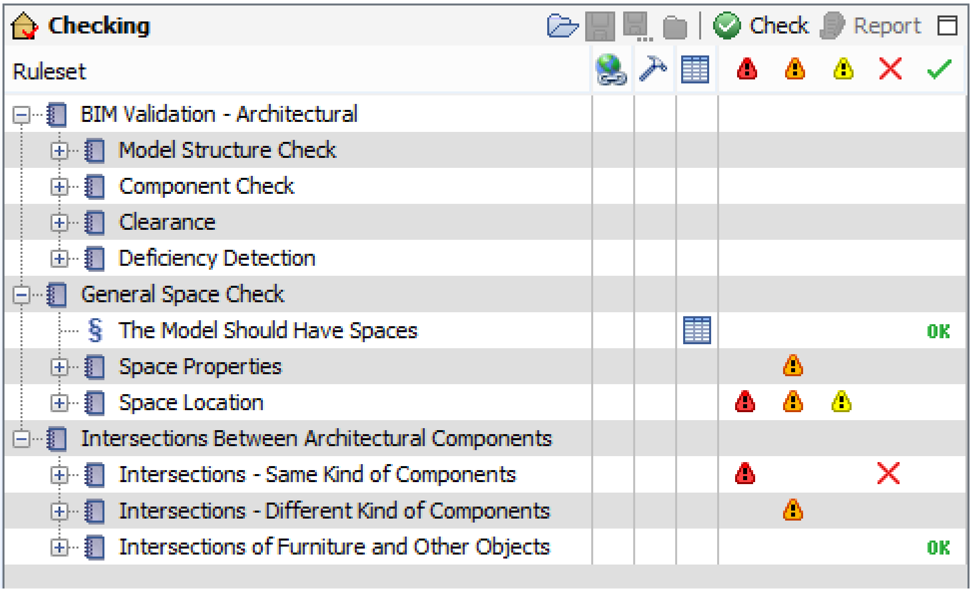

Figure 3.8. Clash detection rule sets in Solibri[30]

- Increase productivity
- Reduced construction cost; potentially less cost growth (i.e. less change orders)
- Decrease construction time
- Increase productivity on site
- More accurate as built drawings

Requirements

- Design Authoring Software
- Model Review Software

Skills:

- Ability to deal with people and project challenges
- Ability to manipulate, navigate, and review a 3D model
- Knowledge of BIM model applications for facility updates
- Knowledge of building systems.

30 https://www.solibri.com/faq/clearing-checking-results-in-solibri-model-checker/

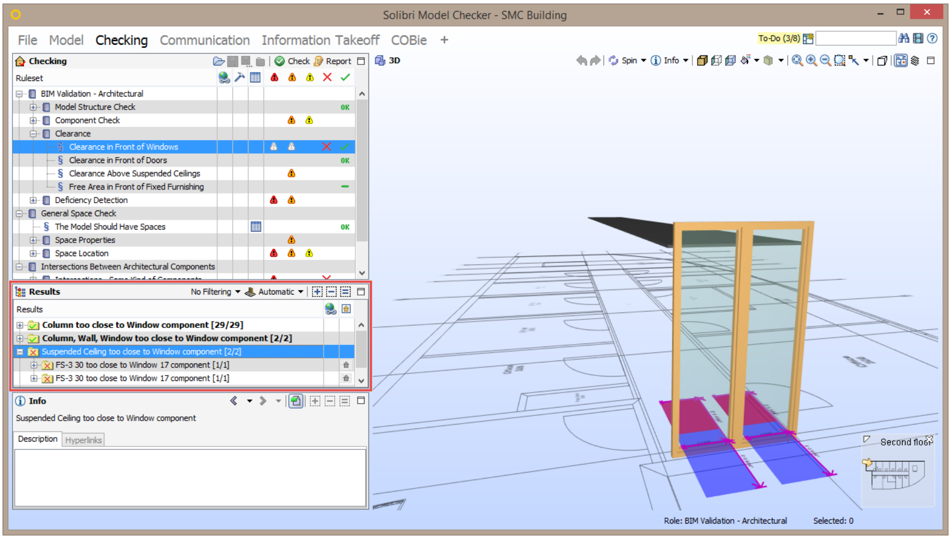

Figure 3.9. An example of a rule based clash detection, the space in front of the door is considered "occupied" by the software. [31]

3.4.6 Construction system design or Virtual Mock-up

A 3D modelling software is used to generate, design and analyse the construction of a building system such as form work, glazing, tie-backs etc. in order to increase planning of resources and sequencing alternatives. Typical areas of interests are the joints and edges between assemblies, which requires collaboration between multiple trades. Virtual Mock-ups can also be 3D printed to increase understanding of the project task.

Value:

- Increase constructability of a complex building system
- Increase construction productivity
- Increase safety awareness of a complex building system
- Decrease language barrier

Requirements

- 3D System design software

[31] https://www.solibri.com/faq/clearing-checking-results-in-solibri-model-checker/

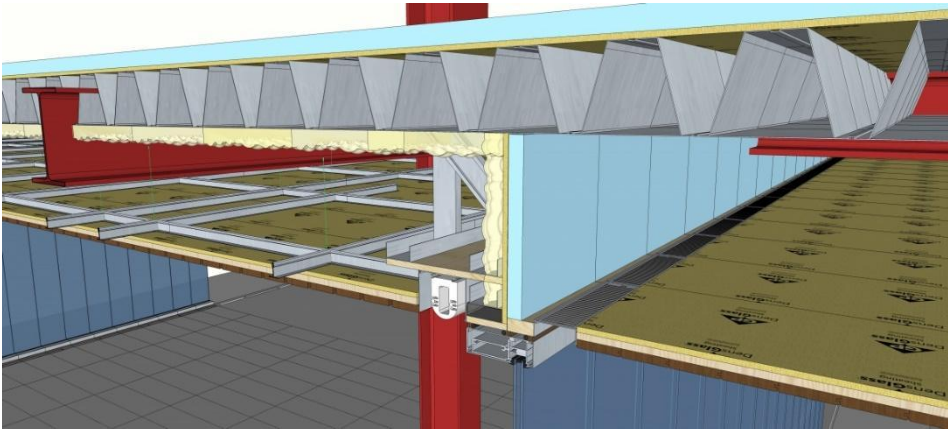

Figure 3.10. An example of a virtual mock-up[32]

Skills:

- Ability to manipulate, navigate, and review 3D model
- Ability to make appropriate construction decisions using a 3D System Design Software
- Knowledge of typical and appropriate construction practices for each component

3.4.7 Digital Fabrication

Digital information is used to facilitate the fabrication of construction materials or assemblies. Some uses of digital fabrications can be seen in sheet metal fabrication, structural steel fabrication, pipe cutting, prototyping (3D printing) for design intent reviews etc. This BIM use assist in ensuring that the downstream phase of manufacturing has minimum ambiguities and enough information to fabricate with minimal waste. It can also be used with suitable technologies to assemble the fabricated parts into final assembly, and is useful for better understanding of the project.

3D printing is used to print out models, and the technology today is able to produce real components of a building directly from the model.

[32] https://blog.sketchup.com/article/ryan-companies-uses-sketchup-pro-virtual-design-and-construction

Value:

- Ensuring quality of information
- Minimize tolerances through machine fabrication
- Increase fabrication productivity and safety
- Reduce lead time
- Adapt late changes in design
- Reduced dependency on 2D paper drawings

Requirements

- Design Authoring Software
- Machine readable data for fabrication
- Fabrication methods

Skills:

- Ability to understand and create fabrication models
- Ability to manipulate, navigate, and review a 3D model
- Ability to extract digital information for fabrication from 3D models
- Ability to manufacture building components using digital information
- Ability to understand typical fabrication methods

3.4.8 3D control and planning or Digital layout

An information model is used to layout facility assemblies or automate control of equipment's movement and location. Detailed control points are created from the model to aid in assembly layout, i.e. layout of walls using a total station with points preloaded and/or using GPS coordinates to determine if proper excavation depth is reached.

Value:

- Decrease layout errors by linking model with real world coordinates
- Increase efficiency and productivity by decreasing time spent surveying in the field
- Reduce rework because control points are received directly from the model
- Decrease/Eliminate language barriers

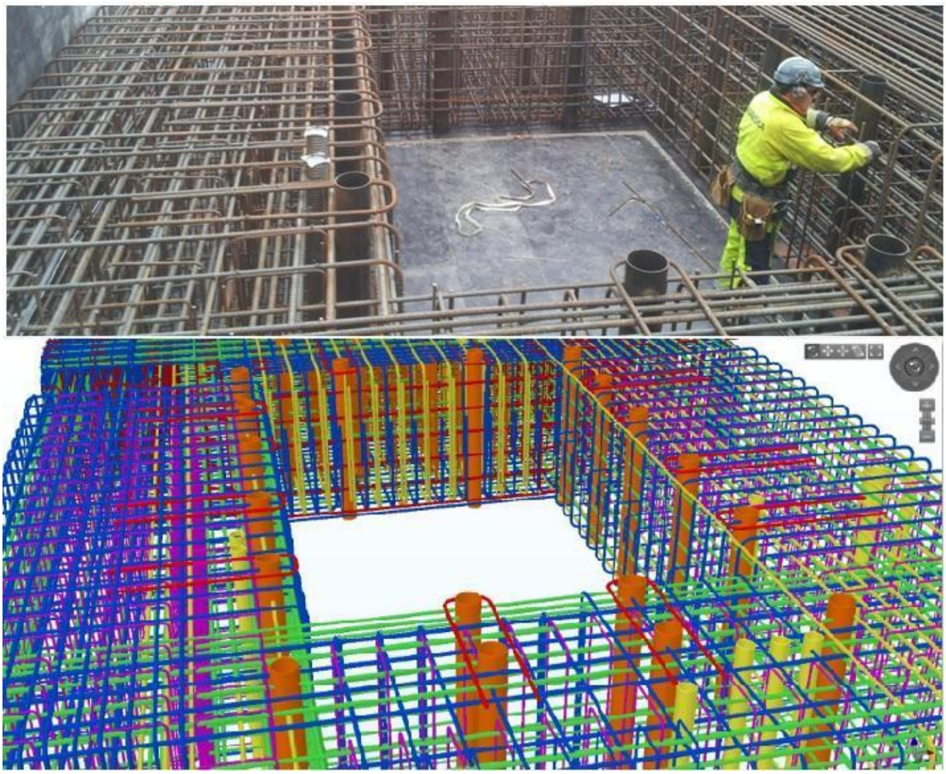

Figure 3.11. An example of digital fabrication [33]

Requirements

- Machinery with GPS capabilities
- Digital Layout Equipment
- Model Transition Software (what software takes model and converts it to usable information)

Skills:

- Ability to create, manipulate, navigate and review 3D model
- Ability to interpret if model data is appropriate for layout and equipment control.

[33] http://www.teklabimsight.com/references/celsa-steel-service-reinforcing-concrete-and-bim

3.4.9 Field/manage tracking

A Field Management software and Field BIM software is used during the construction, commissioning and handover process. It is used to manage, track, task and report on quality (QA/QC), safety, documents to the field, commissioning and handover programs, connected to the information models. The goal of Field management and Field BIM is to ensure conformance to contract documents, compliance to safety regulations, and performance to owner's projects requirements, through BIM-based workflows out in the field and at the point-of-construction.

For an example, the New York Department of Buildings now accepts site safety and logistics information models as a submission, instead of 2D documentation. The department provides a logistics Revit Template with preloaded components such as cranes, access arrows, staging locations and scaffolding.

Value:

- Ability for field personnel to access, read and update, building information models (BIM) in the field.
- Optimize first work and minimize rework due to non-conformances and defects.
- Manage work to complete and correct efficiently with no communication lags and errors.
- Prevent jobsite hazards and at-risk behaviour, and ensure jobsite safety.
- Optimize system and component performance to owner's project requirements.
- Document as-installed information for the record and for handover, at the point-of-construction.
- Accelerate project schedule, time to operations and time to revenue.
- Reduce the operations and maintenance (O&M) handoff, onboarding and uptime process.
- Develop a digital handover asset of structured data and documents, to complement the physical asset.
- Gain real-time visibility into organization, project and stakeholder performance.
- Create a secure history log of field management activity for future audit-ability.
- Identify trends with leading indicators to take proactive, preventive action versus reactive, corrective action.
- Managing and mitigate performance and other risks.

- Avoid contractor call-backs and warranty claims due to construction defects

Requirements

- Design Authoring Software
- Model Review Software
- Field Management Software and Field BIM Software
- Connected, web-based application - cloud-computing
- Disconnected or occasionally connected, local application - mobile computing
- Internet connection
- To access connected, web-based application
- Pad, tablet, slate or other mobile computer device
- To use disconnected or occasionally connected, local application
- Rugged field case (optional)

Skills:

- Knowledge of construction processes and field management processes, including:
- Quality Assurance and Quality Control (QA/QC) processes
- Environmental, Health & Safety (EH&S) processes
- Materials Management processes
- Commissioning (Cx) processes
- Handover or Turnover processes

3.4.10 Record modelling

Record modelling is used to depict an accurate representation of the physical conditions, environment, and assets of a facility. At minimum, the record model should contain information relating to the main architectural, structural and MEP elements. It is the culmination of all the BIM Modelling throughout the project, including linking Operation, Maintenance and Asset data to the As-Built model (created from the Design, Construction, 4D coordination models, and subcontractor fabrication models) to deliver a record model to the owner or the facility manager. Additional information including equipment and space planning systems may be necessary if the owner intends to use the information in the future.

Value:

- Aid in future modelling and 3D design coordination for renovation
- Improve documentation of environment for future uses, e.g., renovation or historical documentation
- Aid in the permitting process (e.g. continuous change vs. specified code.)
- Minimize facility turnover dispute (e.g., link to contract with historical data highlights expectations and comparisons drawn to final product.)
- Ability for embedding future data based upon renovation or equipment replacement
- Provide owner with accurate model of building, equipment, and spaces within a building to create possible synergies with other BIM Uses
- Minimize building turnover information and required storage space for this information
- Better accommodate owner's needs and wants to help foster a stronger relationship and promote repeat business
- Easily assess client requirement data such as room areas or environmental performance to as-designed, as-built or as-performing data.

Requirements

- 3D Model Manipulation Tools
- Compliant Model Authoring Tools to Accommodate Required Deliverable
- Access to Essential Information in Electronic Format
- Database of Assets and Equipment with Metadata (Based upon Owner's Capabilities)

Skills:

- Ability to manipulate, navigate, and review 3D model
- Ability to use BIM modelling application for building updates
- Ability to thoroughly understand facility operations processes to ensure correct input of information
- Ability to effectively communicate between the design, construction, and facilities management teams

3.5 BIM AND PROCUREMENT

When BIM is required by the client the construction contract is supplemented with additional sets of add-on contract clauses, often referred to as BIM protocol. This protocol covers aspects such as licensing of models, permitted purpose of information, liability issues and how information is to be produced, by whom and when.

Following the legal document in appendices, are the LOD table/matrix and Employers Information Requirements (EIR).

In some countries, (UK and Denmark) the employer is advised or mandated to appoint an Information Manager (not to be confused with a BIM coordinator). This individual is responsible for managing the Common Data Environment, project information management and collaborative working, information exchange and project team management. This role does not involve any design responsibility, however it can be undertaken by a project team member with design responsibility or the main contractor.

In the following chapters, the impact BIM can have on the most common / typical procurement methods are discussed.

3.5.1 Design-Bid-Build (DBB)

Design and Build is the most traditional type of delivery method practiced today. The owner has two contracts, one with the designer and one with the contractor. There is no overlap between the design services and the contractor services, and all communication between designer and contractor are through the owner. The design phase ends with a bid, where the owner awards the project to the contractor with the lowest bid. This delivery method may seem simple, but in real-life, number of challenges may rise.

- The bidding documents have not been reviewed by a contractor, and therefore numerous of miscalculations can be discovered later in the process, which generally leads to added cost.
- Errors discovered by the contractor can slow down the construction process and are costly.
- Due to lack of communications between design team and contractor, the project may have cost overruns, when cost tracking is not done continuously throughout the design.
- Increased risk of litigation might arise, due to lack of collaboration.

- The delivery method is slower, since the full construction drawings must be completed prior to bid and construction.

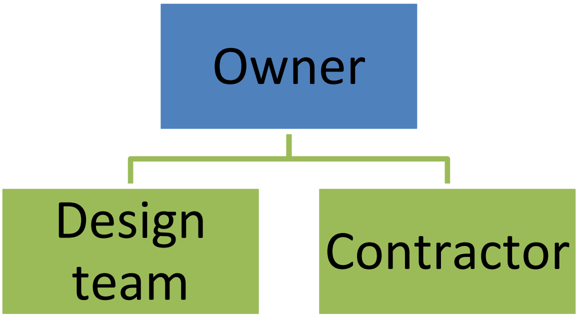

Figure 3.12. Design Bid Build.

When BIM is applied in Design-Bid-Build (DBB) method, the design team is using BIM mostly for their own benefit or due to owner's requirement. The value BIM offers to DBB are:

- Creates a foundation for contractor and subcontractors to coordinate MEP systems (Mechanical/Electrical/Plumbing)
- Can save the subcontractor time and money by allowing them to prefabricate their systems using the provided models.
- Makes the initial estimating process easier for the contractor, although this depends on the quality of the model.
- Gives another level of clarity to all members on the design and construction of the project, previously only afforded in 2D.

3.5.2 Construction management at risk (CMAR)

Here the contractor is brought in during the design phase and the agreement between the owner and contractor is often in two parts. The first part is specifically for the design phase services and the second part for the construction services. CMAR is a convenient procurement method for applying BIM, but the owner must create or require a plan that illustrates how BIM will be used or else CMAR will have the same difficulties as DBB.

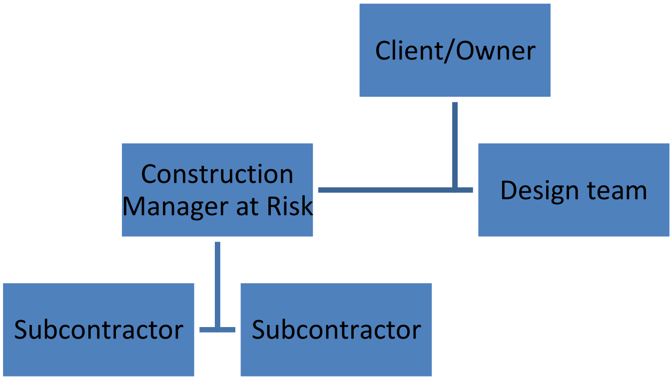

Figure 3.13. Construction Management at Risk.

The major benefit is the early contractor involvement. However, special conditions can arise if the design team is not willing to share their models or is not required to produce contract models. The timing of contractor and key subcontractor involvement can also affect how BIM can be applied to the project.

3.5.3 Design Build

The Design-Build procurement is considered the best fit when BIM is applied. In this method, partners services overlap and all partners are required to function as team. Here the owner should define project requirements and budget, as the Design-build objective is to deliver the facility in accordance to specified requirements and budget. The design-build method is about "designing to the budget" instead of "budgeting to the design", i.e. "*Design-Build breaks the mould of traditional roles and responsibilities and demands a collaborative team environment based on trust*".[34]

[34] Hardin & McCool, 2015 p. 57

Figure 3.14. Design Build.

This delivery method gives the team a possibility to use constructible models during the design phase, enabling constructability issues to be solved in the process. The models can then evolve throughout the design phase, offering a leaner process and allowing the team to be proactive on solving various issues. Furthermore, this method encourages innovation and has the potential for zero change orders. The challenges of this method lies in the trust-based collaboration between the partners involved, which is required for successful implementation.

3.5.4 The Construction manager

If BIM is to be applied to a construction project, the first steps to be taken by the construction manager is to pinpoint a BIM/VDC coordinator, with the right skills. Now a-days it can be difficult to get staff with both experience in constructions and BIM skills. Individuals with BIM skills often have limited field and/or practical experience. A construction manager (CM) should therefore have a team of people involved; a single person might not be enough.

The next step is to assess the project in terms of identifying the risks and determining how best to minimise them using BIM. This is done through a BEP (BIM Execution Plan), where the BIM goals and uses are defined, the BIM project execution process is designed and information exchange requirements are developed.

The third and last step is to define the supporting infrastructure, such as software, hardware and workforce. Every construction project is unique, and one BEP is not "one size fits all". Therefore, it is critical to assess the project execution and develop a BEP for each project, choose which BIM uses is to be applied and then execute them.

The construction manager or the BIM manager should always ask the following questions when implementing BIM on a project:

- What is the delivery method?

- Where is the AE team in the design process?
- Is there a BIM contract requirement?
- Are the designers modelling?
- What is the level of development?
- Are they going to share the models?
- When is the BIM kick-off?
- Where is the BEP?

3.5.5 BIM Coordinator / BIM manager

In every BIM project, a BIM coordinator or a BIM Manager should be defined. Their role is to deliver the BIM uses into the project. In some projects, no 3D models are available from the designer, but visualizing the project in 3D, clash detection and quantity take-off is of much value. In this situation, the BIM Coordinators role is could be to model the project, make sure there are no clashes, and base the quantity take-off on the model data. In another situation, a 3D model is available, but the concrete reinforcement is complex and the designer is unable to include it in the model. Here the BIM coordinators role could be to add the reinforcement to the model, make 4D sequencing, produce workshop drawings and quantity take-off.

The role of a BIM coordinator can be various, depending on the project, the risks and the execution. The coordinator must be "agile" and ready to take on challenges such as patiently selling the value of BIM to those involved in the project.

The position requires an organized person, detail-oriented with the ability to manage multiple tasks at a time, as well as people skills. Remember that when BIM is implemented, people will need to change their behaviour and reaction to traditional processes. The technology to apply BIM may be available, but the staff is not necessarily trained to apply BIM and may therefore try to make BIM work in the way they are used to do things, rather than modify their traditional way of work to fully take advantage of BIM. This adoption takes time and patience, as the BIM learning curve is rather steep.

CHAPTER 4

BIM IMPLEMENTATION

(D. PHILP, S. MORDUE)

4.1 INTRODUCTION

In this chapter, we explore the key considerations for the successful implementation of Building Information Modelling (BIM).

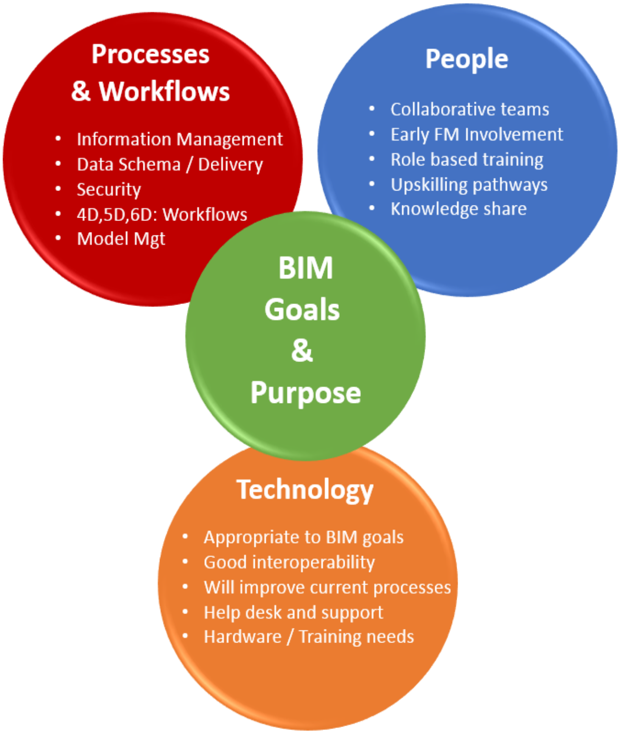

Figure 4.1. Key elements of BIM

There are various reasons you might want to implement BIM, for example:

- In response to a Client need such as a mandate or a contractual requirement
- As part of an overall organisational change programme
- To get better outcomes on your project even if the client hasn't asked for it
- It is part of your organisations standard operating procedures
- To test a BIM enabled workflow or technology

Irrespective of your drivers for doing BIM it is important that the purpose and proposed outcomes are clearly defined with clear consideration given to the three undernoted dominant themes from figure 4.1.

The NBS Periodic Table of BIM amplifies these BIM implementation themes taking its inspiration from the periodic table of elements, the table presents all the main elements of BIM, i.e. Strategy, Foundations, Collaboration, Process, People, Technology, Standards, Enabling tools, and Resources.

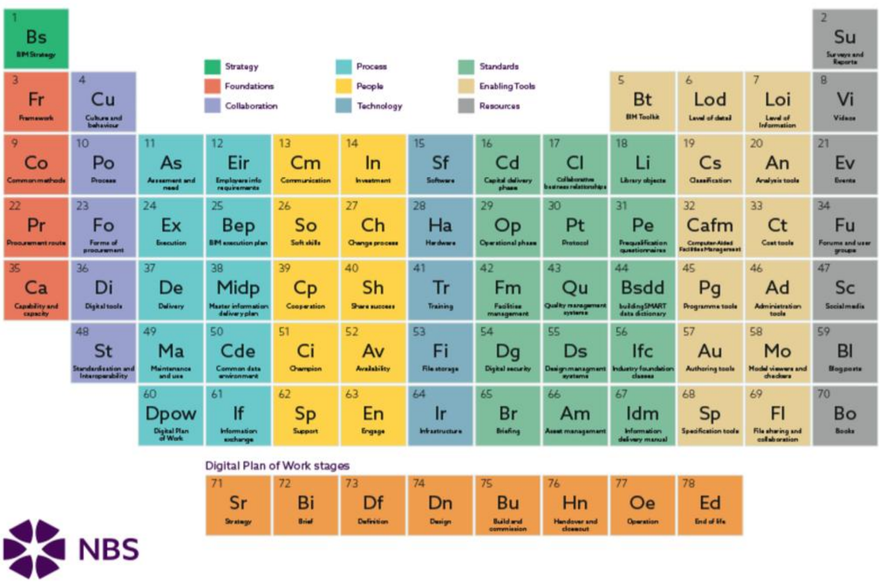

Figure 4.2. NBS Periodic table of BIM[35]

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[35] www.thenbs.com/knowledge/periodic-table-of-bim

Strategy

Your starting point should be your BIM strategy. It is important to understand what your company is trying to achieve with BIM and how and when you will implement the strategy. The strategy requires consideration of the supporting foundations, processes, technology, tools and people that you require.

Foundations

In order to achieve advanced BIM processes requires a firm foundation of efficient systems for communication, information exchange, and data transfer. You need to consider your approach for managing the production, distribution, and quality of construction information. It also needs the right procurement route that will set the appropriate environment for collaboration. Make sure that you establish your current BIM capability and capacity. This will determine your BIM readiness status and focus your thoughts on the practical changes you may need in the future.

Collaboration

At the heart of BIM is collaboration. With the right processes and tools, BIM results in better and more efficient ways of working. With the right digital tools, you can benefit from coordinated information by allowing you to collaborate effectively. This may require cultural and behavioural changes to create the right attitudes for sharing.

Process

Consider how and where you can make improvements in your current processes. Understand what a best-practice workflow looks like and ensure that information is universally structured regardless of author. Understand information requirements during the whole project life cycle so that best value is achieved through the whole project timeline.

People

People are a key element of a BIM strategy, which is often overlooked. Provide clear communication to your colleagues as to why and how you intend to implement BIM and gain support by engaging BIM champions, as well as getting support from senior management. BIM implementation requires changes in process so make sure that you share success among the team and provide individuals with the support and training that they may require.

Technology

Ensure that you have the right technology in terms of software and hardware, to support your BIM aims and objectives. As you move into a digital environment, you should consider how and where data is stored and by what means to share and publish information in a security minded way.

Standards

Get to know the applicable standards, procedures and supplementary documents available to you that will assist with your strategy and help achieve collaborative BIM. More countries around the world are embracing BIM either as a top-down approach such as mandating BIM at a government level, or a bottom-up approach such as a demand from the supply chain.

Enabling Tools

Consider the enabling tools that will help design, develop, deliver, and maintain the built asset. You may require a number of different enabling tools for specific tasks and functions. Before you make an investment, consider what tools are available to you for free.

Resources

Make use of access to information by considering what resources are available to you. The internet and social media have created a valuable online community of support.

4.2 CREATING A BIM STRATEGY

Organisations adopting BIM should ideally adopt a long term strategy with clearly identified significant goals that they wish to achieve on their journey. These goals and how they will be delivered should be well articulated and visibly communicated within an organisation along with their supply chain. A typical journey plan is illustrated in the diagram below showing how standards and outcomes for BIM progressively become embedded into the organisation as business as usual. The strategy should be aligned with business objectives.

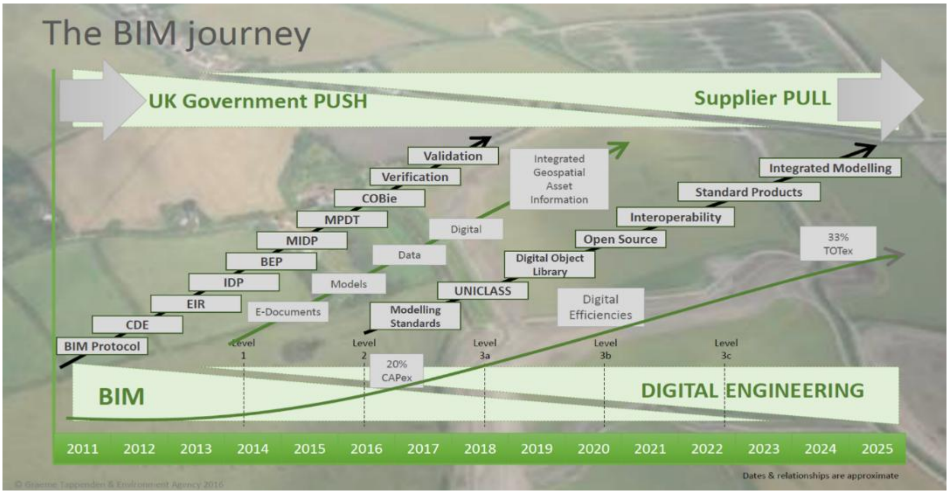


Figure 4.3. The BIM journey, past and future.[36]

As part of this planning process the organisation needs to ask, where are we now and where do we want to be?

Benchmarking current level of organisational BIM maturity around capability and capacity are a good starting point. Areas to consider:

A.) Collaborative working practices
B.) Information Management processes
C.) Model authoring
D.) Model co-ordination and reviews
E.) Virtual Design and Construct workflows e.g. 4-6D
F.) Data exchanges and validation

It is also advantageous to create an end-to-end process diagram to understand the organisations data flows, key milestones where information is required and its purpose. A BIM overlay to support and enhance and digitised this process can then be created.

The strategy should then cascade into a BIM Implementation plan clearly setting out in detail the activities needed to support it and roles and responsibilities of those delivering it.

[36] Source Environment Agency, United Kingdom. Author G.Tappenden

4.3 ENSURING BETTER INFORMATION MANAGEMENT

BIM is equally about "Information Management" as it is about modelling and being able to access the right information, at the right time and in the right format is a key benefit. The information derived from the models will also enable better decision-making and delivering more efficient and effective activities especially in the operational stages.

Successful Information Management connects project stakeholders, automates process and builds in governance through data validation activities. Benefits include:

- Eliminating both duplicate data collection and storage in two places
- Integrating and streamlining project and asset management information systems.
- Delivering better collaboration by enabling all stakeholders to work upon the same accurate and up-to-date information.
- Reducing project lead times by streamlining sharing and workflow during feasibility and design.
- Providing remote access to asset information and removing the need for paper based documentation.
- Building a database of quality asset data (costs, interventions, materials and more) to inform optimum asset strategies and plans.

It is key therefore that any BIM implementation plan has a clear information management strategy and underpinning technologies such as a common data environment (CDE). The CDE is a single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams in a managed process.

The CDE is a means of providing a collaborative environment for sharing work and can be implemented in a number of ways. CDE technology solution can be very different on small and large projects, it may use a project server, extranet, a file-based retrieval system or other suitable toolsets from free web-based file sharing applications or more sophisticated enterprise software

The CDE has "gates", or sign-off procedures, that allow data/information to pass between the sections and facilitates the exchange of information by creating a standard process for:

- File sharing
- File Management Procedure
- Recording Input / Output

4.4 UNDERSTANDING INFORMATION NEEDS

Fundamental to the BIM process is gathering information throughout the project lifecycle that is appropriate, well defined and will support the decision making process. In most cases it will also be needed to support the operational delivery and the organisation's asset management strategy.

It is therefore essential that at the beginning of any project an information delivery plan, an IDM, be developed that defines the flow of information across the project stages and the supporting data transactions.

This process should ideally be instigated by the employer or their professional team. It is especially beneficial for an operational representative to be involved in defining the data requirements for the in-use needs, explicitly starting with the end in mind. Understanding the Computer Assisted Facilities Management (CAFM) systems that the data from BIM will transfer to is important as is an early test of transferring data between the project and asset model be undertaken.

The information delivery plan will vary for each project however it should clearly establish for each exchange:

- The information to be delivered and its attributes e.g. a model
- A description of the deliverable e.g. steelwork model ground to tenth floor
- Level of Definition, Development or Detail [Depending on your choice!]
- Exchange formats e.g. IFC, Native BIM
- Owner
- Date required to issue
- Classification code

It is especially important that the level of information of information growth be aligned with each stage and the information requirements it is responding to. This level of information growth has many different acronyms depending on your geography or perspective.

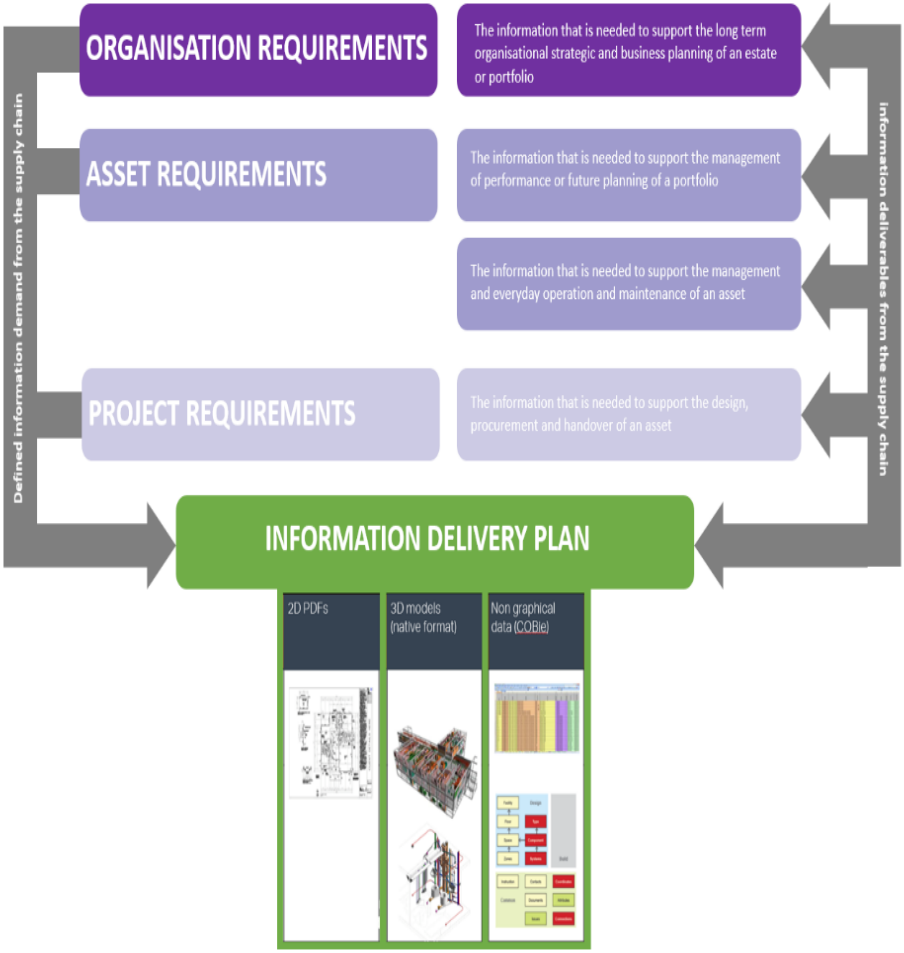


Figure 4.4. Stepwise development of an information delivery plan [source: D. Philp].

The most commonly used is the American Institute of Architects publication "AIA E202-2008: Building Information Modeling Protocol Exhibit" to help define, essentially, the content of any part of a BIM project. The AIA refers to this as the "Level of Development (LOD)" which aims to specify the accuracy and reliability of model elements within the models in order to define clarity for downstream expectations and uses (see Table 4.2). Model elements within building systems may have to go through multiple LOD's throughout its lifecycle as the design progresses through the virtual design and construction process.

The UK also uses LOD, but here it is defined as "Level of Definition" which is made up of Level of Detail (geometrical) and Level of Information (non-graphical attributes).

In practice an LOD code is assigned against each building component or system at each progressive stage of the project so the complete team knows what to expect.

Table 4.1 Levels of Model Development

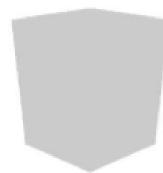
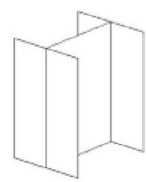
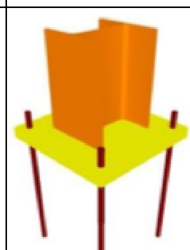
UK	**US**	**Description:**
LOD 1		Brief: a model communicating the performance requirements and site constraints. Building models would be block models only.
LOD 2	LOD 100	Concept: a conceptual or massing model intended for whole building studies including basic areas & volumes, orientation, cost. e.g. for an HVAC system, this might include block models of the plant room locations and distribution risers.
LOD 3	LOD 200	A design development model, "generalized systems with approximate quantities, size, shape, location and orientation." e.g. for an HVAC system, this would be more what the architect above expected: duct runs modelled to approximate routes, but at an accurate overall size to include maximum potential sizes without detail of flanges or accurate radii of bends.

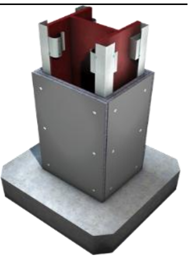
LOD 4	LOD 300	Production, or pre-construction, "design intent" model representing the end of the design stages. Modelled elements are accurate and coordinated, suitable for cost estimation and regulatory compliance checks. This LOD would typically be a model suitable for production of traditional construction documents and shop drawings. e.g. for an HVAC system, this is what the structural engineer was hoping for: accurate duct sizes & locations.
LOD 5	LOD 400	Installation: an accurate model of the construction requirements and specific building components, including specialist sub-contract geometry and data. This model would be considered suitable for fabrication and assembly. Architects or engineers would rarely produce objects at this level. e.g. for an HVAC system, the cut lengths of duct runs, fixings; a CAM model.
LOD 6	LOD 500	An "as built" model showing the project as it has been constructed. The model and associated data is suitable for maintenance and operations of the facility.
LOD 7	N/A	N/A

The UK and US Level of model development are illustrated in Figures 4.4 and 4.5, respectively.

The information defined for each LOD level consist of graphical representation depending on what is to be modelled, and the Level of Information (LOI) depending on what non-graphical information the building element should contain. The fundamentals of LOD are described in Table 4.2 below.

Table 4.2. Fundamentals of the Level of Development for BIM objects.

Level of Development	Description	Graphical representation of a steel frame column
LOD 100 / **Level 1**	The Model Element may be graphically represented in the model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model element, i.e. cost per square foot, tonnage of HVAC etc., can be derived from the model elements. LOI: Type, dimension (approx..)	
LOD 200 **Level 2**	The Model Element is graphically represented within the model as a generic system, object, or assembly with approximate quantities, size, shape, location and orientation. Non-graphic information may also be attached to the Model element.	
LOD 300 **Level 3**	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location and orientation. Non-graphic information may also be attached to the Model Element.	
LOD 350 **Level 4**	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, orientation and interfaces with other building systems. Non-graphic information may also be attached to the Model Element.	

LOD 400 **Level 5**	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location and orientation with detailing, fabrication, assembly and installation information. Non-graphic information may also be attached to the Model Element.	
LOD 500 **Level 6**	The Model Element is a field verified representation in terms of size, shape, location, quantity and orientation. Non-graphic information may also be attached to the Model Element.	
N/A **Level 7**	In use…	

The information delivery plan should form part of an overall Employers Information Requirements for BIM as part of the tender enquiry. The Employer's Information Requirements (EIR's) is a document which sets out the information to be delivered, BIM standards and processes that the suppliers should adopt during the project delivery process. The EIR document should be utilised through all tiers of the project, so an organisation required to submit information to another party on the project has to follow the EIR.

The EIR will form part of the appointment and tender documents in order to enable tier one suppliers to produce their BIM Execution Plan (BEP). A compliant BEP will demonstrate how the requirements outlined in the EIRs will be met. The EIR is normally created early as possible, and before the appointment of design or construction suppliers.

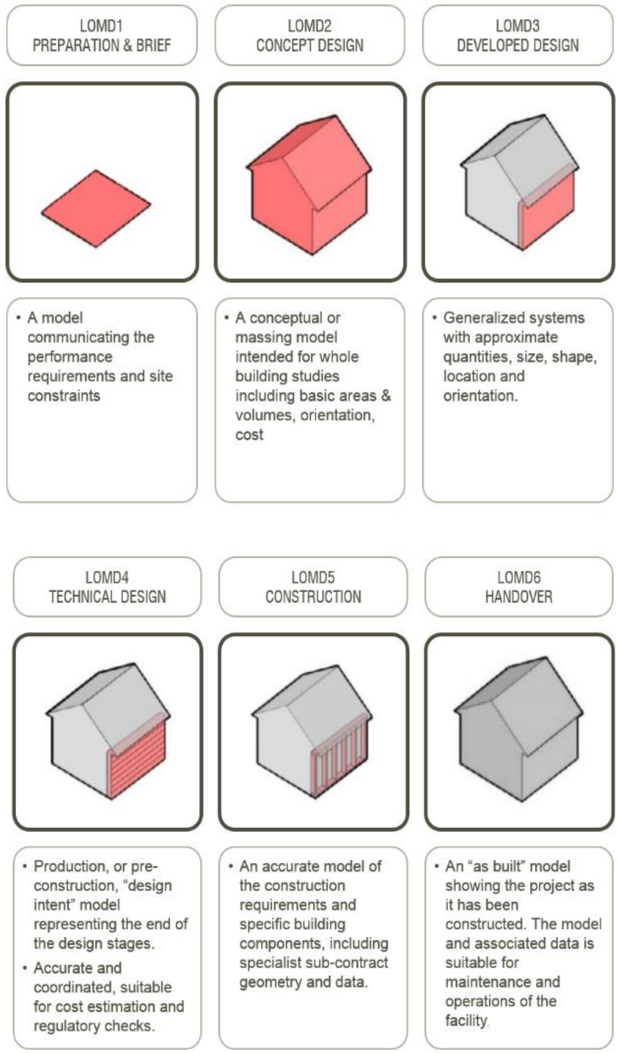


Figure 4.5 The UK Level of model definition. Source: http://www.evolve-consultancy.com/resource/bim-brief/lod-lod-loi

The content of the EIR typical covers three areas:

- Technical – details of software platforms, definitions of levels of detail etc
- Management – details of management processes to be adopted in connection with BIM on a project

- Commercial – details of BIM Model deliverables, timing of data drops and definitions of information purposes

A sample of typical EIR contents is illustrated in Table 4.3.

Table 4.3 A sample of the content of typical Employers Information Requirements (EIR).

Technical	**Management**	**Commercial**
Software Platforms Data Exchange Format Coordinates Level of Detail (general) Level of Detail (components) Training	Standards Roles and Responsibilities Planning the Work and Data Segregation Security Coordination and Clash Detection Process Collaboration Process Health and Safety and Construction Design Management Systems Performance Compliance Plan Delivery Strategy for Asset Information	Timing of Data drops and project deliverables Clients Strategic Purpose Defined BIM/Project Deliverables BIM-specific competence assessment

4.5 LEGAL AND COMMERCIAL ISSUES

It is important that legal and commercial issues are properly addressed prior to the tender process and then incorporated within the contracts and appointments. These include:

- Clearly defining information requirements, standards and processes to be followed within the invitation to tender
- A Model Production Delivery Table defining the information exchanges including responsible parties, levels of data growth and exchange formats.
- Liabilities for use of models and permitted purposes as to what the models can be relied upon for e.g. producing costs

- Intellectual property and model ownership
- Amendments to contract wording to incorporate BIM
- Roles and responsibilities including the client's role in the process

It is always wise to have your legal team review any tender enquiry to ensure that the legal requirements can be met.

4.6 THE BIM EXECUTION PLAN (BEP)

The BIM Execution Plan (BEP) plan explains how the information modelling aspects of a collaborative BIM enabled project will be carried out. The goal for developing a BEP is to stimulate planning and direct communication by the project team during the early phases of a project. Since there is no single best method for BIM implementation on every project a tailored execution strategy is designed for each project, emphasizing the project goals, the project characteristics and the capabilities of the team members.

The BEP is produced by the supplier (on behalf of the supply chain for the project) and is submitted to the employer or their project manager to explain how the information modelling aspects of a project will be carried out. It usually details:

- Project goals and value identification
- Project team roles and responsibilities associated with BIM
- BIM Standards, methods and procedures
- A resourced Information Delivery Plan made up of the individual plans from each contributor to the modelling process

The BEP is usually submitted in two phases - pre and post-contract and should respond to any requirements that the employer has set out.

It is important that the supply chain contributing the BEP demonstrate IT and BIM resource capabilities, competence and experience.

The contents of a typical post contract BEP are listed in Table 4.4.

Table 4.4 Contents of a typical post contract BEP. [source: Construction Project Information Committee (CPIX) http://www.cpic.org.uk/]

PROJECT INFORMATION
INFORMATION REQUIRED BY THE EIR ● Planning or work and data segregation ● Co-ordination and clash detection ● Collaboration process ● Health and safety/CDM Management ● Compliance plan
MANAGEMENT ● Roles, responsibilities and authorities ● Major project milestones ● Project information model delivery strategy ● Survey strategy ● Existing legacy data use ● Approval of information ● PIM Authorization process
PLANNING AND DOCUMENTATION
● Revised project implementation plan ● Agreed project processes for collaboration and information modelling ● Agreed matrix of responsibilities across the supply chain ● Task Information Delivery Plan (TIDP) ● Master Information Delivery Plan (MIDP)
STANDARD METHOD AND PROCEDURE ● Volume strategy ● PIM Origin and orientation ● File and layer naming conventions ● Agreed construction tolerances for all disciplines ● Drawing sheet templates ● Annotations, dimensions, abbreviations and symbols ● Attribute data
IT SOLUTIONS ● Software versions ● Exchange formats ● Process and data management systems

4.7 ROLES AND RESPONSIBILITIES

Clearly defined roles and responsibilities are essential on any BIM project and these should be embedded into any relevant contract or design appointments.

Information Management roles should be implanted into existing project roles such as the lead designer or main contractor however on certain larger size projects or where the parties do not have sufficient capability then the appointment of a standalone Information Manager role should be considered.

The scope of the Information Manager role typically encompasses:

- Scoping and helping procure the Common Data Environment (CDE)
- Managing the Common Data Environment (CDE)
- Project information management
- Collaborative working, information exchange and project team management

It should be noted that the responsibilities of the Information Manager and the BIM Manager are often quite different. It is important to note that the Information Manager has no design responsibility. The role is to make sure that the project team follow appropriate agreed BIM processes and procedures and ensure data is secure. Anyone can undertake the role of the Information Manager, and person undertaking the role may even change during the course of the project. For example, at pre-contract this may be managed by a member of the design team or an external consultant. Once the contract is awarded, the lead contractor may take responsibility for the information management role.

The BIM Manager role may likely already be encompassed within the scope of service of the lead designer or undertaken by the main contractor. One of the main goals of the BIM Manager or a BIM Co-ordinator is to federate the models and facilitate the clash reporting activities and chair the collaborative model review meetings. The BIM Manager will also likely be involved with overseeing the quality of the model and ensuring it is developing in concert with the standards set out in the BIM Execution Plan.

On most projects the BIM Manager will also take the lead on ensuring interoperability between the various technology platforms and defining the appropriate workflows and exchange formats. Table 4.5 gives an overview of the roles played by the different parties involved in the BIM process.

Table 4.5 An overview of the role of key personnel involved in BIM.

Personnel	**Role**
BIM Specialist	Creates the process and requirements, develops the BEP, implements BIM within the organisation through hiring and training staff. Oversees the process.
Information Manager	Responsible for setting up the CDE and managing information between the different parties. This role has no design responsibilities.
BIM Manager / BIM Coordinator	Generates the BIM uses according to the BEP prescriptions. Produces, coordinates, and/or receives the BIM deliverables, such as Information Models, 4D schedules etc.
BIM Technician / Draftsman	Creates the BIM deliverables, such as Information Models, 4D schedules etc.
BIM user	The viewer, the end user of a BIM product, such as the construction worker, the client etc.

4.8 BUILDING THE PROJECT INFORMATION MODEL

Once the BIM Execution Plan (BEP) has been agreed the project information model (PIM) can commence. The PIM is progressively developed to provide the data required by the employer and the project team at each stage of the project. Each discipline such as the architect, engineer, civil and infrastructure consultants will prepare their own discipline models. Once suitably progressed and approved the models are shared with other members of the design team for coordination and ongoing design development.

Once the design models are fully co-ordinated they can publish for virtual design and construction workflows.

The PIM process is illustrated on the fig. 4.6.

The PIM becomes larger and more complex as the project progresses it is important that the breakdown of the model be considered.

Once the project information model is complete it can be archived for the client or preferably the basis for an Asset Information Model to facilitate a digitised facilities and asset management strategy

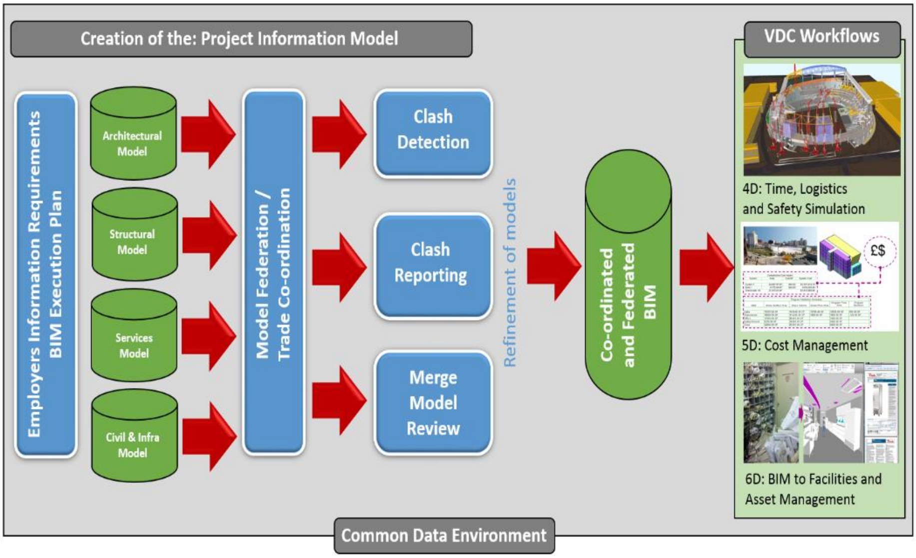


Figure 4.6. Creation of a project information model, an example of a common data environment [source: D. Philp].

4.9 UPSKILLING

Ensuring that all project members have the appropriate skills and knowledge to implement BIM consistent with their role and responsibilities is key to successful delivery. This may often require some degree of upskilling or teaching staff new skills, depending upon their current starting point.

There are different strategies that can support this from internal training using your subject matter experts, on-line training or external providers who will often be needed for technology training sessions.

- Training course - Such as online, distance learning or classroom
- Books and trade publications
- Social media - Such as Twitter, Linkedin, Blog posts
- Industry event - Such as conferences and trade shows
- Professional Institutes
- Masters programs in Universities
- Government and industry websites - Such as the SFT BIM Portal, UK BIM Task Group, buildingSMART,

4.10 BIM AND THE CONSTRUCTION MANAGER

BIM and its convergence with other digital workflows such as Virtual Design and Construction (VDC) can greatly support the construction management functions of a project helping support collaborative working processes and ensuring that the same accurate data can be accessed throughout the supply chain.

Key to VDC are the concepts of: Pull Planning and 4D BIM workflows which are key components of the lean and digitised construction project. Whilst individually each offer benefits the real value is realised when these two themes converge. Both share the same value proposition of improvements in productivity, risk and schedule reliability.

Pull planning is a project-based production system in conformance with lean principles such as the Last Planner (see Fig. 4.7). It is a collaborative approach that includes and empowers those who are directly responsible for supervising the work activities on the project.

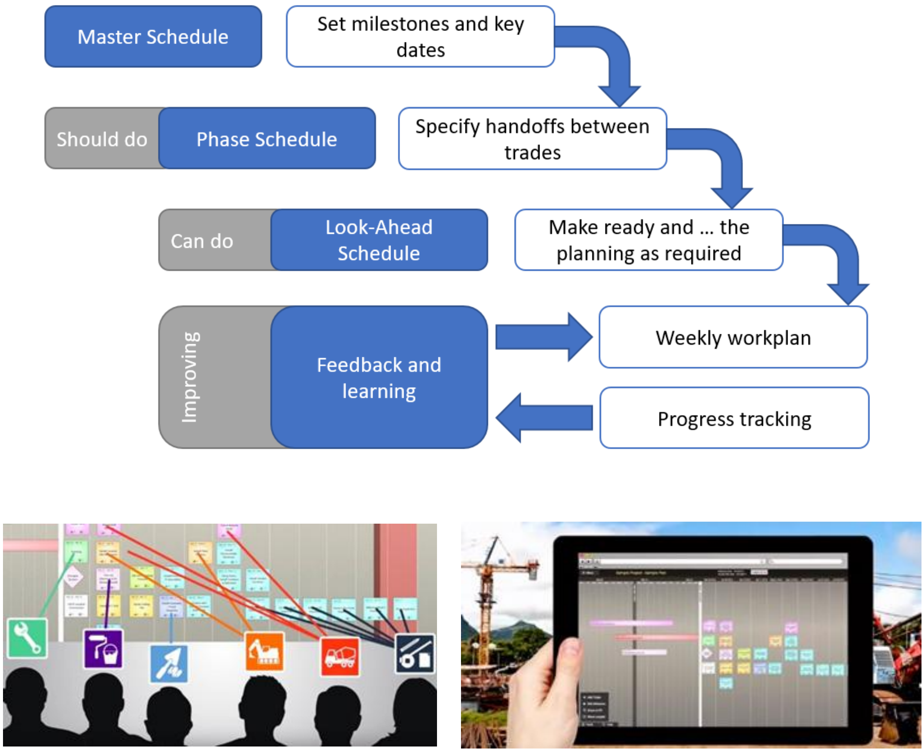


Figure 4.7. An example of a project-based production plan.

As mentioned in section 3.3, 4D BIM adds a time dimension to BIM enabling a sequence of work activities to be represented visually and simulated across a schedule time line as illustrated on figure 4.9. It is important that the Work Break-down Structure (WBS) and Level of Definition (LoD) are given proper consideration at the early stages.

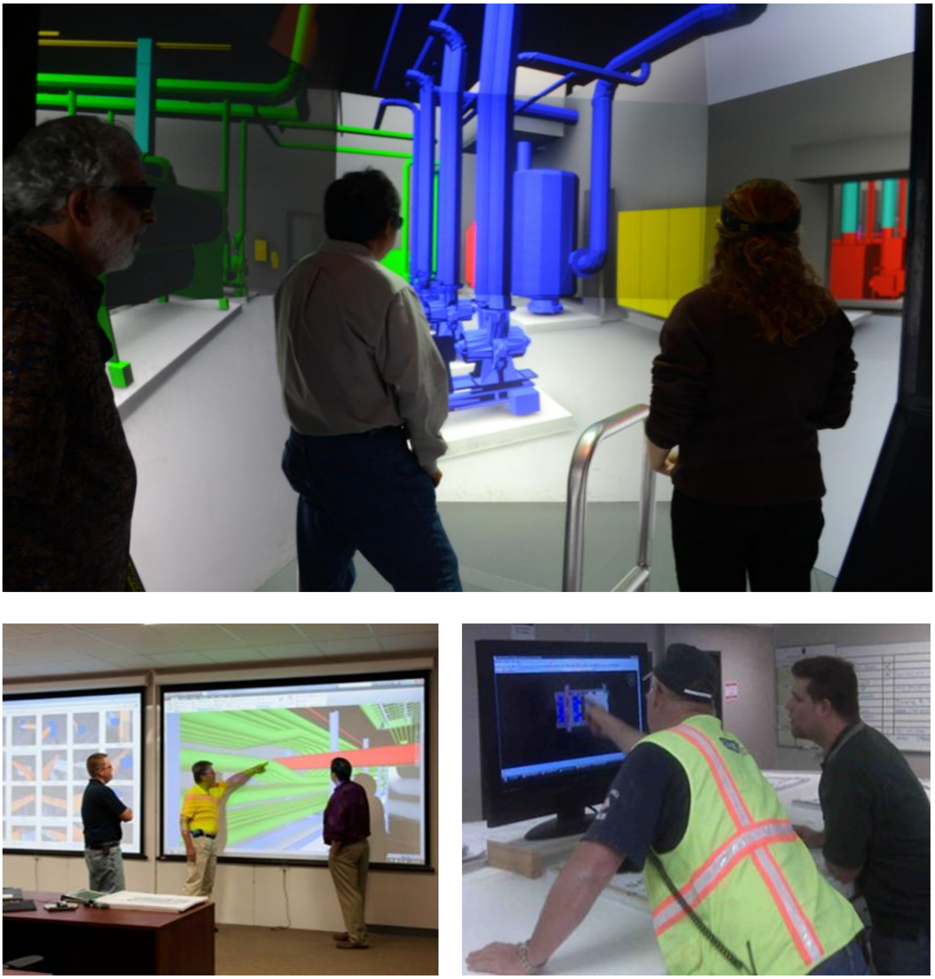


Figure 4.8. An example of a Big Room environment.

These workflows would ideally be undertaken in either a "physical" or "virtual environment often known as a "Big Room", BIM Lab, VDC Lab or CAVE environment. The goal is to improve collaboration through greater team integration. The Big Room essentially defines a team approach (see Fig. 4.8) for collaboration and quick resolution to issues for preconstruction and the construction process.

Physical Big Room is a physical structure or temporary location for project site collaboration. The Virtual Big Room defines a cloud-based process where project members utilize newer technology for just in time coordination and collaboration to reduce travel and project costs. The Big Room can also be used to manage the coordination cycle as illustrated in Fig. 4.10.

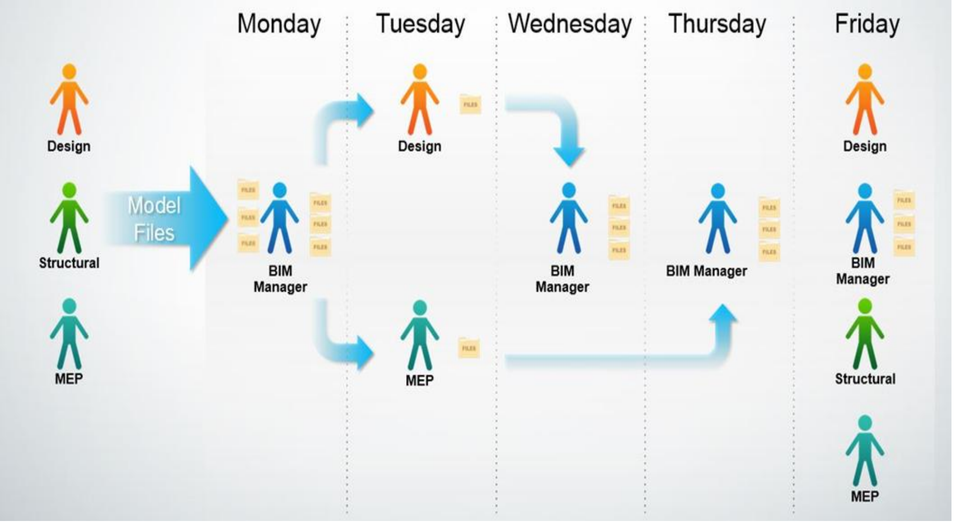


Figure 4.9. An illustration of a typical coordination cycle.

Monday through Thursday: Trades work collaboratively to resolve clashes in zones dictated by the construction schedule. Standard practice should be to federate models every time the file is saved Monday through Thursday. At a minimum, trades are required to federate models at close of business each day (each Subcontractor will be responsible for uploading their latest trade specific authoring and analysis models for Thursday's scheduled Coordination Meeting).

Thursday: The design team and General Contractor (GC) meet to review the Clash Reports provided through BIM reporting tools for example Autodesk Glue. The consolidated model will be reviewed for coordination purposes. Any conflicts found will be discussed by design team members and a resolution will be determined. GC will note the assigned corrections and log them using the mark-up function of BIM

GC VDC Engineer will review integration of the latest uploaded design discipline and trade specific models. GC will monitor merged models (including trade specific models) along with Clash Reports.

Figure 4.10. Coordination meeting during the construction phase. [37]

Friday: subcontractors will be expected to have made the corrections from Thursday's coordination meeting and upload the revised trade specific authoring and analysis. GC will run conflict detection and analysis of corrected items.

After the coordination team has confirmed coordination procedures are complete for a designated area, Subcontractors are to submit printed shop drawing for review and approval by MEP coordination team. Once Coordination team approves shop drawing, a document will then be transmitted to Architect and Engineer of record for final approval.

4.11 SOFT LANDINGS

BIM can also support a projects Soft Landings strategy; simply defined as "aligning the interests of those who design and construct an asset with those who subsequently use it".

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[37] Lean Construction Institute

Key Principles:

- Soft Landings are a key element of the design and construction process maintaining the 'golden thread' of the building purpose through to delivery and operation
- Early engagement of end user and inclusion of the soft landings champion on project team during the design/construction process
- Commitment to aftercare post construction from design and construction team
- Post occupancy evaluation and feedback to design/construction team and lessons learnt captured for future projects

The typical soft-landings process is illustrated in the diagram below.

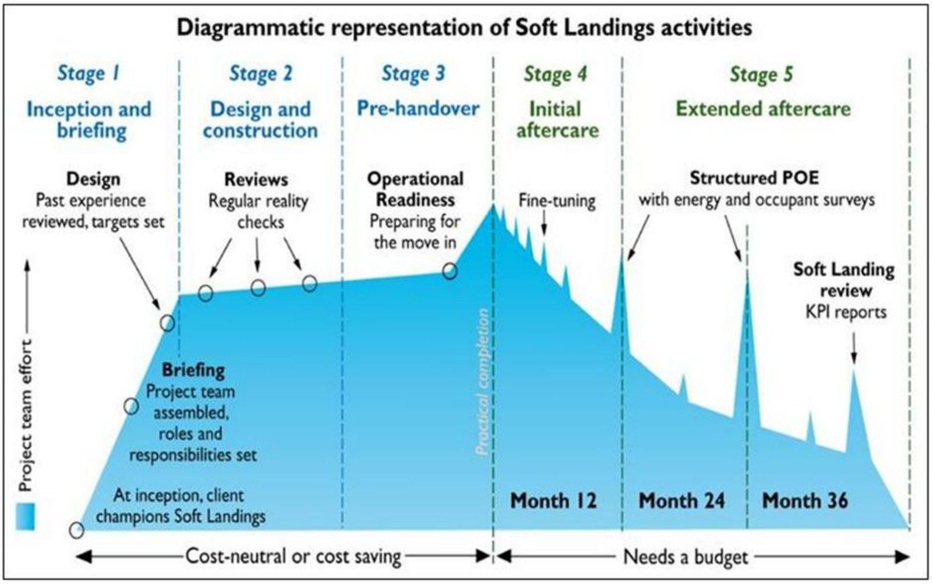

Figure 4.11 Diagrammatic representation of Soft Landings activities. (source BSRIA)

The rich model based environment provided by BIM can be used to simulate and test use and operations in a 3D fully immersive environment. The same way designers check for design clashes a Soft Landings Champion will check for operational clashes and maintainability issues. During the construction period the model acts as a vehicle to capture operating and commissioning data. The models should be used pre-handover to let asset operators test run operations, plan for maintenance and validate the required information. When BIM is used for Soft Landing activities a few points/issues should be considered. Table 4.5 considers Softlandings best practice and what you should and shouldn't be doing.

Table 4.5 BIM Do‘s and Don‘ts to achieve a soft landing of a project.

Do: ● Have clear purpose as to what you want to achieve through BIM implementation ● Use a common data environment (CDE) ● Have a BIM Execution Plan which everyone is working to ● Create a collaborative environment for reviewing models and sharing information ● Set out information requirements and appropriate levels of definition ● Ensure that your supply chain are capable of delivering information in digital formats especially manufacturer data ● Ensure that BIM requirements are clearly established in the contract or appointment documents ● Think about data security measures appropriate and to reduce the risk of loss or disclosure of information ● Use open file exchange formats where possible such as IFC or COBie
Don't: ● Think of BIM as purely creating geometric models – it is also about better information management ● Create a CAD model first and then do BIM retrospectively ● Over complicate – make sure your strategy is simple and proportionate ● Overload the geometrical model it should link to other databases such as cost where practical ● Base your BIM journey on one pilot project – there is a learning curve to go through ● Don't exchange your models without having validated first ● Forget to test the interoperability of the various BIM technology platforms ● Ignore the need to refine processes to suit more collaborative and lean working ● Just train a few BIM experts make sure that all of your project team are upskilled to meet their job profile ● Stop after one project – BIM is a journey and should be thought of in terms of business change management

Table 4.6 shows a checklist of which activities should be controlled and checked when BIM is implemented.

Table 4.6 BIM Implementation Checklist

Ref	Activity	Notes
1	Have BIM / VDC Goals and success metrics been clearly established for the project?	
2	Has the plan of work (key stages) for the project and exchange points been identified?	
3	Have the plain languages questions and corresponding data requirements been established for each stage?	
4	Is there a common data environment for the collaborative sharing of information across project stakeholders?	
5	Is there a framework in place to support collaborative and lean working practices?	
6	Have information requirements been properly defined for both capital and operational delivery stages?	
7	Have roles and responsibilities been properly defined and articulated in appointments and contracts?	
8	Have standards for information management and data delivery been defined and articulated in appointments and contracts?	
9	Has built asset security been considered?	
10	Has BIM been clearly articulated in the tender documents including an information delivery plan?	
11	Has the supply chain capability to deliver BIM against the employer's requirements been assessed?	
12	Has a BIM Execution Plan and Model Production Delivery Table been prepared?	
13	Have BIM requirements been included in the appointments and contracts?	
14	Has project interoperability been tested?	
15	Have design coordination meetings been established to drive BIM based collaboration?	
16	Have BIM quality assurance procedures been established especially for data validation?	
17	Has a trial data exchange to CAFM systems been undertaken?	
18	Have processes been established to maintain the models during the operational stages?	

CHAPTER 5

ASPECTS OF THE INTERFACE

(D. PHILP, S. MORDUE)

In this chapter, we explore the key considerations for the successful implementation of Building Information Modelling (BIM).

5.1 BIM AND A TECHNOLOGICALLY ADVANCED CONSTRUCTION INDUSTRY

Digital technology is reshaping the construction industry, radically changing the way we design, build and operate our buildings and infrastructure. Building Information Modelling is already transforming the construction industry but that is only the beginning.

Similar to the world of advanced manufacture construction is in the early days of Industry 4.0 a ubiquitous connection of people, things and machines. Enabled by Level 3 BIM environment products, transport and or tools are expected to "negotiate" within a virtual marketplace regarding which production elements could best accomplish the next production step. This will create a seamless link between the virtual world and the physical objects within the real world.

Over the coming years this technology will converge with the internet of things (providing sensors and other information), advanced data analytics and the digital economy to enable us to design new infrastructure more effectively and maintain it more efficiently.

All ready we are witnessing automation in the construction process including data driven generative design where using cloud computing, the software explores all the potential permutations of a solution, rapidly generating design alternatives. It tests and learns from each iteration what works and what doesn't.

These technologies will undoubtedly disrupt the traditional construction market place it is important that organisations therefore consider the following future wise strategy:

- Be data-centric rather than software-centric; it is easier to shift data rather than to keep upgrading models to suit new proprietary software updates.
- Find time for research and development; keep an eye on evolving processes, systems and business models especially in adjacent sectors who have already made a successful digital transformation.

Don't invest in new technologies without due diligence and testing whether it will meet with your functional requirements.

It is also important to consider that the future of making things will be both digital and physical with more focus on design for manufacture and assembly (DfMA) and the mutualism with accurate digital models. Whilst demand is growing for each individually, the real benefits happen when these two themes converge. Both share the same value proposition of technological advancement, which unlocks improvements in safety, quality, productivity and cost.

BIM can be used to explore the opportunities of increasing site productivity and reduce reliance on skilled labour, as illustrated in Figure 5.1.

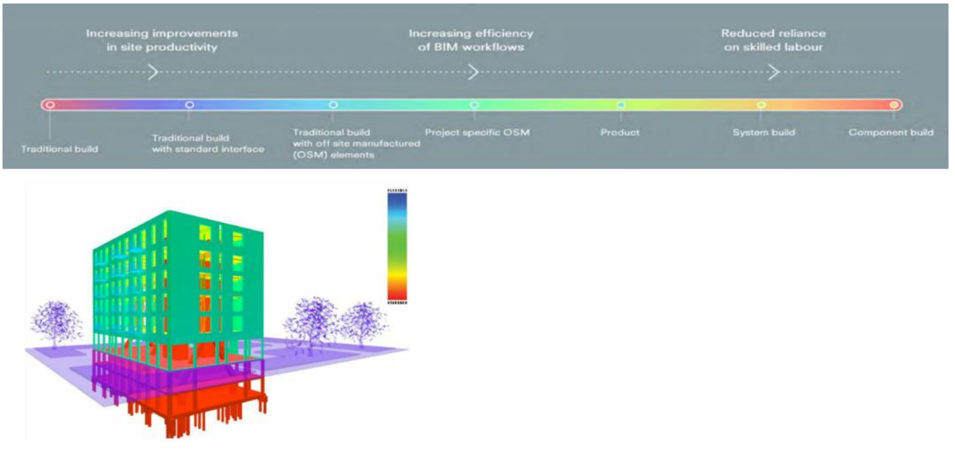

Figure 5.1. Opportunities of increasing site productivity and reduce reliance on skilled labour (Source: Bryden Wood)

5.2 SELECTING THE RIGHT TOOLS AND TECHNOLOGIES TO SUPPORT THE IMPLEMENTATION OF YOUR BIM STRATEGY

BIM is a process enabled by technology. While technology is a vital ingredient to help you achieve better outcomes for assets, there are a number of consideration that need to be made before you invest in new tools. Firstly understand your current starting position by investigating the quality of your existing systems and processes. Remember to include basic devices such as phone systems as well as offsite tools such as laptops and mobile phone which play an important part in your wider network of connected business systems and devices. Before you consider software solutions, make sure you have the right infrastructure such as high speed internet connections and supporting hardware.

Hardware refers to the physical components that will support your BIM implementation strategy. Key considerations include:

- **Hard-drive, Memory & Processing speed:** How much space or room needed for information and software programmes and the speed in which the computer can carry out these tasks. Software vendors usually state recommendations
- **Processing speed:** How fast your computer can complete tasks and run programmes. The faster the better when handling large model files.
- **Monitor:** A large wide screen or alternatively two monitors allows for multiple tasks to be open on different screens.
- **File storage:** Information should be stored so that it can be retrieved by others if needed. Make sure that you follow a robust security procedure to secure sensitive data, which may include personal information, intellectual property and commercially sensitive data.

5.2.1 Using Mobile Devices

The use of mobile devices and technologies bring many benefits to the field. The mobile nature of the devices means that they are portable and lightweight. Combined with an internet connection, mobile devices offer the ability to inspect design, mark drawings and models, report issues, carryout inspections and snagging. Feeding directly back to the information model reduces chances of human error as less inputting and double handling of data.

5.2.2 Software

There are many different software vendors and solutions available on the market, each with their own pros and cons, it is important that you undertake some prior thought and planning. You may wish to consider the benefits of operating in the cloud. 'Cloud computing' is an all-encompassing term that relates to the sharing of resources over the internet. In this regards it is not a specific technology or software solution. Using the power of the web, information can be access regardless of software installed or geographical location, greatly promoting collaborative working.

No one single tool will be able to do produce a BIM project by itself. Rather you may need a number of tools that are capable of undertaking a variety of tasks. It is important that you pick the right tool for the job, and not the other way around. You should also consider your current technology stack as well as free software, tools and plugs available. Table 5.1 illustrates a broad selection of tools available.

Table 5.1 BIM enabled tools and technologies

Tools	**Purpose**
Design Authoring Software	Provides the ability to aid the design and construction by generating data for multiple uses, in 2D and 3D. Tools may be specific to a discipline and use parametric capabilities using a combination of graphical information and data. ● Revit (Autodesk) ● Tekla Structures (Trimble) ● MicroStation (Bentley) ● Archicad (Graphisoft).
Scheduling software	Provides ability to schedule works and by contractors on a project. Some software integrates the graphical model with time based capabilities to provide construction sequencing (often referred to as 4D Modelling) ● Vico Office (Trimble) ● Synchro Pro (Synchro Software) ● Navisworks (Autodesk).

Tools	**Purpose**
Cost tools	Provides for quantity takeoff and estimating. Costing capabilities may be linked to Design authoring tools via plug-ins. ● Solibri (Solibri) ● Navisworks (Autodesk) ● Vico Office (Trimble).
Model Review Software	Provides ability for project team members to view, navigate and interrogate model information. Some software also offer additional functionality such as model checking for clash detection. ● Solibri Model Viewer (Solibri) ● TeklaBIMsight (Trimble) ● Trimble Connect (Trimble) ● Rendra (Rendra O) ● Dalux BIM viewer (Dalux)
Field Management Software and Field BIM Software	Provides the ability to collaborate, report and feedback to a project model, using a combination of mobile and cloud technologies ● BIM 360 Field (Autodesk) ● Trimble Field Link (Trimble)
Computer-Aided Facilities Management tools (CAFM)	Provides the ability to manage, report, track and plan facilities functions. May include or interface with CAD systems, Information models and Computerised Maintenance Management Systems (CMMS) ● YouBIM ● Mainmanager ● FM: Systems

5.2.3 Proprietary versus Open file formats

The flow of information is critical for collaboration and interoperability, as it allows use between different authoring and downstream applications, e.g. facilities management, structural modelling and analysis applications.

With assets having a useful operational life spanning many years, you need to think about how you access the data in the future. Just because a software vendor supports a particular software and file format now, doesn't always mean that this will be the case in the future. Having information in an open standard means that you will more likely that a tool will be available in the future to read and use this information.

A Proprietary file format is a file format that is native to a certain software programme, that only that programme can recognize. An example of this is Microsoft Word. When you save a document, it is saved as a .docx file, which is native to Microsoft word and may not be recognised or supported by other programmes. To allow the document to be recognised by other applications, the document can be saved or exported as a Plain text file (.txt) or a rich text file (rtf). These are examples of an Open file format that is not tied to any particular software vendor.

Industry Foundation Class (IFC)

buildingSMART promotes IFC as a neutral product model supporting the building lifecycle and opens up membership to all interested parties. It was first developed by an industry consortium formed by Autodesk in 1994. To assist the development of a non-proprietary standard it was renamed the International Alliance for Interoperability in 1997 and reconstituted as a not-for-profit alliance.

buildingSMART promotes Industry Foundation Class (IFC) as a neutral product model supporting the building lifecycle and opens up membership to all interested parties. IFC is an example of an industry-wide open and neutral data format for data exchange. Essentially, IFC provides the 'guidelines' or 'rules' to determine what information is exchanged and is able to hold and exchange data between different proprietary software applications. This includes a wide variety of information, from geometry, to relationships between components, and thereby it becomes a platform to solve interoperability issues.

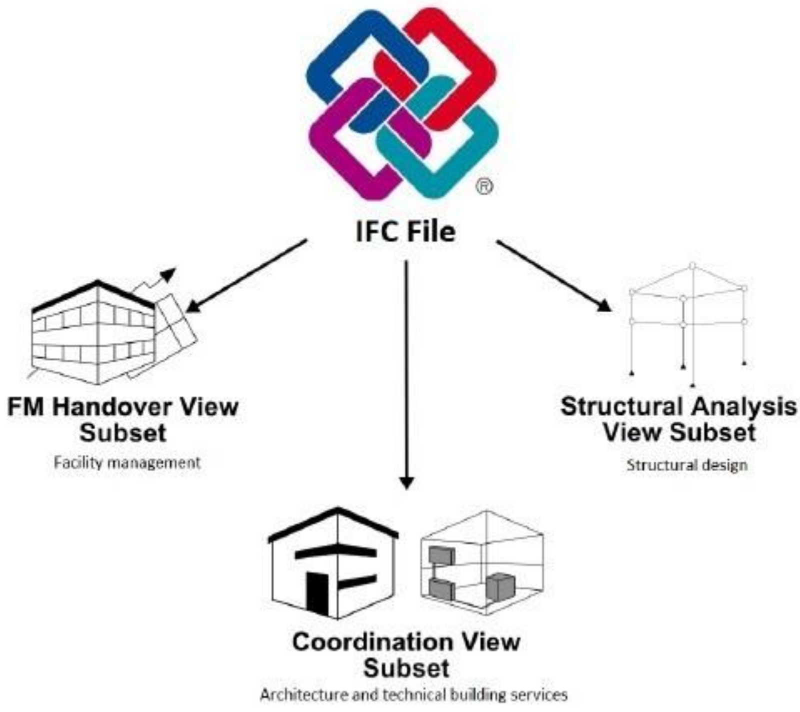

Figure 5.2. An example of the Industry Foundation Classes (IFC) scheme

The current IFC release is IFC4. This is registered with ISO as official International Standard, ISO 16739:2013. You can view the schema via the buildingSMART website:
(http://www.buildingsmart-tech.org/ifc/IFC4/final/html/)

Certification

It is important to understand that to achieve interoperability relies not only on robustness of the IFC schema, but on also the implementation of it by the software packages interfacing with it. buildingSMART operates a certification scheme. This is to promote consistent and reliable implementations of the IFC Specification across different software vendors and software solutions. Most BIM software support IFC capability. Either import and/or export of IFC model data. You can find more information on the certification procedure along with the current certified software on the buildingSMART website (http://www.buildingsmart-tech.org/certification)

The process of exchanging data

The Information Delivery Manual (IDM) is the buildingSMART standard for processes connecting BIM to relevant business processes by offering an understanding for all stakeholders of a project on what is needed for appropriate exchange of information. It provides detailed specification of the information that a particular user (architect and building owner) needs to provide at any given point in time and groups together the information that is required in associated activities, such as cost estimating.

IFD / BuildingSMART Data Dictionary (bSDD) – Mapping of terms

The International Framework for Dictionaries (IFD) or the BuildingSmart Data Dictionary (BsDD) is a data dictionary, which brings together disparate sets of data into a common view for the construction project, independent of whether that information comes from a product manufacturer or the designer. It can cope with different languages. This product also serves as an agreement on terminology.

Model View definition (MVD)

When working in a collaborative environment, it is unlikely that other consultants will require the whole model to be exchanged. For example, just a particular view, or type of information may be required. To address the many information exchange requirements, a Model View Definition (MVD) can be used. A MVD is a filtered view or section of the IFC schema to suit different information purposes. For example, a coordination view, a structural analysis view and a Basic FM Handover view.

BIM Collaboration Format Support (BCF)

BCF (BIM Collaboration Format Support) is an open file XML format that supports the communication workflow in a BIM process. This file format is also developed and supported by buildingSMART Alliance. When for example, a co-ordination is performed with an appropriate software, the person performing the co-ordination receives an IFC file from the designers, imports it into the software and exports the results in a BCF file format. The designer then imports the BCF file to his model, which shows him where the clashes are in the model.

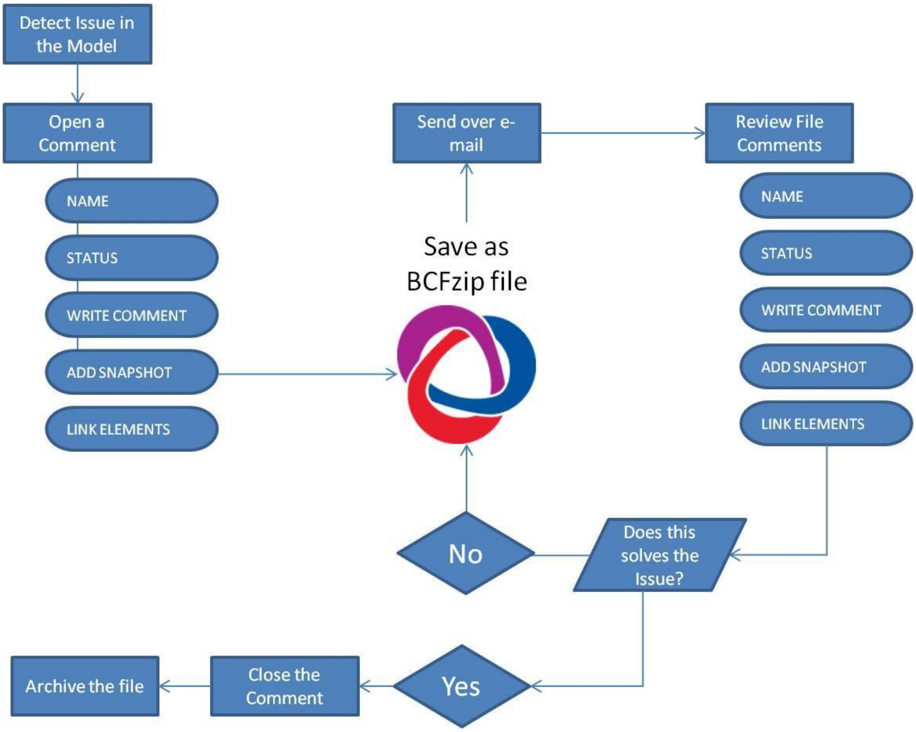

Figure 5.3. BCF workflow

5.2.4 How deliverables align with Construction Managers tasks need to support decision making

Value is achieved by BIM through the exchange of open, shareable data. The move from documents to data means that data can be digitally re-worked for many purposes such as extraction, analysis or verification and that these processes can be automated.

From the start of a project, the EIR sets out the information to be delivered across the project lifecycle. Within the EIR, the specific information requirements should be aligned to the project stages and each referenced to the needs of the client at each stage. It is likely that there will be multiple EIR on a project, with the contractor's supply chain responding to a contractor-led EIR that will have different information needs.

Clear communication of the information requirement is very important but clients are not all expected to be able to define precisely what data they require from suppliers. In accordance with the BIM Level 2 strategy, it is likely that the EIR will include a series of PLQ that enable the client to communicate the information requirement for services at various stages in the project lifecycle.

5.2.5 Plain Language Question (PLQ)

A PLQ is simply a broad information requirements, against which a supplier will respond with data taken from models and other sources. Clear communication of the information requirement is very important but clients are not all expected to be able to define precisely what data they require from suppliers.

It is likely that the EIR will include a series of PLQ's that enable the client to communicate the information requirement for services at various stages in the project lifecycle. PLQ's may begin as broad outline questions. These may then be broken down into more details component questions. The rate of information growth within the model is dictated by how much information is needed to answer each PLQ.

The UK Ministry of Justice has created a set of PLQ's that, as a client, they intend to answer at each stage of a construction project. Key decisions such as whether to proceed to the next work stage or not will be made based upon the answers to these questions. The full list of questions can be viewed via the NBS website https://www.thenbs.com/BIMTaskGroupLabs/questions.html. The table 5.2 shows an extract of PLQs.

Table 5.2: Plain language questions examples

Stage	PLQ	Information required to satisfy the PLQ
Strategy	Have the stakeholders needs been captured?	List of key deliverables and requirements, where needed supported by measures. These may be captured in a model or a specific requirements management system.
	What is the initial view of revenue (FM) cost?	Major maintenance and capital replacement costs identified. Energy use aspiration. May be a spreadsheet at this stage.
Brief	How are stakeholder needs captured?	An "electronic brief" that is in a format that may be used for automated validation of proposals.
	What is the available site?	3D laser and / or radar survey generated solid model and CDF Grid including ground conditions and existing structures. (May be existing information from a reliable BIM or GIS source). Google and/ or OS Maps.
	What is the initial view of capital cost?	Model of the development's volumes Schedule of internal volumes, land, floor, wall and roof areas or service runs aligned with generic cost data as aggregated by the cost estimator Fabric not normally represented. Budget breakdown.
Concept	Can the designers show the project can be delivered safely?	Construction logistics demonstrated, highlighting how high risk elements have been avoided or controlled.
	What is the preliminary cost estimate?	Identification of key items that will influence the facilities in use. Schedule of capital costs based upon aggregated quantity and rate take off from the model and an associated schedule of assumptions. Whole life cost assessment based upon this plus in use simulation results and documented maintenance assumptions. Confidence level: design contingency of 20>25%.

	Has the delivery schedule been validated?	Time attributes associated with the assembly sequence as planned in the model.
Defi-ni-tion	Is the design developed to demonstrate detailed proposals for site layout?	Development model superimposed upon 3D laser survey model viewable from a range of pre-agreed perspectives. 2D general arrangement drawings, plans, cross sections and elevations, produced from the model.
	Is the design developed to demonstrate detailed proposals for coordinated design intentions?	Zones allocated to demonstrate adequate space for coordination, including building services. Survey of site, Point cloud data processed to form 3D site model. High definition photography overlay on 3D survey.
	Is the cost plan robust (firm)?	Quantity take off from BIM Schedule assumptions based on build sequence used in BIM. Evidence that results of virtual and/or real prototyping of innovative and complex elements of the design have been incorporated into the BIM. Assumptions of a predicted range of operational costs for key activities. Confidence level: design contingency of 10>15%.
De-sign	Is there sufficient design information to get a reliable tender (model, drawings, specifications, schedules, room data, bills of quantities, finishes, walk through etc.)?	Model with both geometric, specification and performance data, with confirmation of the absence of clashes between building, structure and services. Confidence level: design contingency of 5>10%.
	Have lead times been obtained for procuring the facility's engineering systems?	Time sequencing incorporated into the model.

	If existing services are in place, have method statements been produced for how these will interface with the new works?	Method statements referenced in model. Procurement plan for permits, access etc. coordinated with construction sequence.
Build and Co-mmi-ssion	How will BIM be managed and exploited in this project?	A contractual BIM execution plan and protocol for the project defining different levels of design maturity for each project phase, who will develop the content, to what standards, who will be authorised to use it, for what purpose, how it will be coordinated, who will own what and how information incompatibilities shall be resolved. This is to include the means and protocols for the communication of information between parties.
	How will the client be consulted with respect to detailed changes to designs during construction?	Model based information and product samples shall be provided.
Hand over and Clo-se Out	What has been built?	As built model Positional accuracy attribute information 3D laser or radar survey generated model information. Commissioning information comparing planned performance with actual.
	How does a specific product / element perform?	Object test result & date attribute information for transfer to FM systems. Update of O&M manuals to reflect amended [performance and settings.

Construction Managers will have to answer to specific PLQs by carrying out tasks and deliverables. A task is a service that is carried out by a particular role for which the output is typically a set of documents. For example, during the handover and commissioning stage, the client will want to know exactly what has been built. The task to prepare the As Built model information, may be assigned to the Construction Manager. The output could typically be an information model, 3D laser or radar surveys or report comparing planned performance data with actual performance data.

A deliverable can be described as a service that is carried out by a particular role in which specific data is delivered that represents a physical object in the asset. An example object may be a space such as a type of classroom or a system such as the lining of a tunnel.

The amount of information that the deliverable requires will be dictated by the required Level of Graphical and non graphical data .

5.2.6 Construction Operation Building Information Exchange (COBie)

The purpose of COBie is simple. To capture critical information for building owners and operators to assist with the management of their assets within a facility.[38] The focus of COBie is on 'Managed Assets'. These are assets which will requires regular inspection, checks maintenance and in some cases the replacement of parts. Having easy access to this data is essential for the smooth operation and running of an asset during its useful life.

The standard is a non-proprietary data format for the publication of a subset BIM models and specifies how non-graphical information, needed by the facility manager, are delivered throughout the whole life-cycle of a facility and can be viewed in design, construction and maintenance software, as well as in simple spreadsheets, which allows the standard to be used and viewed in projects regardless of technological sophistication. The aim is to deliver asset data as a distinct entity from geometric information.

5.2.7 Classification

Vast amounts of data is generated within a BIM project by many different people. Typically there are three principal types of person that handle information in BIM. [39]

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[38] http://www.bimplus.co.uk/management/deconstru5cting-co3bie-us-army-des3igners-desktops/

[39] Mordue S, R Finch, BIM For Construction Health and Safety, RIBA Publishing (2014)

- Generator - Produce basic information (eg Architect produces specification and contributes to the PIM)
- Reviewer - Assess and analyse information (eg service engineer
- Receivers - End user of information (eg Contractor requires product details and installation instructions)

Whether a generator, reviewer or receiver of information, a classification system allows all project participants to quickly identify and find things within the model is fundamental to BIM. Classification systems such as Uniclass 2015 (UK) and Omniclass / Uniformat (USA), CCS (Danmark), NS 8360 (Norway), TALO 2000 (Finland) and VDI2552 (Germany) have been defined by the Public sector in different countries.

Classification enables:

- The digital searching for like "things" in models
- The automated combination of models because all "things" are consistently classified
- The aggregation of like "things" in models for the purposes of measurement, purchasing, maintenance etc.
- A common language for all people constructing and managing assets
- The effective "benchmarking" of measured values across similar assets

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CHAPTER 6

CASE STUDIES

(D. PHILP, S. MORDUE)

6.1 CASE 1 - MET OFFICE SUPERCOMPUTER HALL, DEVON

Client: Met Office

Lead Contractor: Willmott Dixon

Led Architect: Stride Treglown

The sci-fi movies Tron and 2001: A Space Odyssey were the futuristic design inspirations behind the £20 million Met Office supercomputer complex, a new nerve centre for climate science in East Devon.

The cutting-edge 3,000 sq m facility, at Exeter Science Park, comprises a giant IT hall where a £97m supercomputer will develop a clearer picture of our climate, and a two-storey hexagon-shaped Collaboration Building for use by climate scientists.

The brief was for a full BIM Level 2 project, compliant with BS 1192 and PAS 1192 standards, to improve design coordination and clash detection and ultimately provide a data-rich Asset Information Model (AIM) to underpin future running and maintenance.

Architects Stride Treglown led the entire BIM process and acted as lead BIM coordinator and lead information manager. Tom Gould, BIM coordinator at the firm commented: "The project started in 2014, when BIM Level 2 was unveiled but few projects were doing it. We thought, let's make this a good case study and try to deliver it inline with all the PAS and BS documents. Although we missed out some of the 4D and 5D aspects of Level 2, we delivered the key electronic data live in the geometry and in spreadsheets, in spades."

The architect developed a series of "rule sets" in software to optimise clash detection across architecture, structure and M&E models, all coordination errors were uploaded to a cloud-based BIM collaboration platform. This enabled project team members to download clashes into Revit then swiftly rectify them and synchronise changes back to the cloud, saving time and money before construction started.

Strides worked with main contractor Willmott Dixon and the Met Office to identify the most important assets for maintenance and operation and the level of detail and information required in the AIM, to be used by facilities managers post-handover.

Ralph James at the Met Office commented" Working directly with the team we established early engagement with our Computer-Aided Facility Management supplier to ensure our vision of future use and activity around the BIM model and its outputs would be of long term value allowing for the more agile management of our assets."

Services contractor NG Bailey sourced the majority of BIM model objects for the huge amount of M&E equipment in the IT hall directly from suppliers and product manufacturers. Where 3D models were not available, placeholder models with attached data, were developed to include in the native Revit model.

A fully-integrated COBie exchange 6 report was produced, as spreadsheets containing information such as bar codes, serial numbers, warranty start dates, replacement costs, and other additional parameters.

The Met Office plans to use its BIM asset model to inform the development of future projects on the site, in the process helping save time and money, says James: "The use of BIM provides the opportunity for future contractors to federate their work and offer more efficient planned delivery of change activity as the site evolves," he concludes.

6.2 CASE 2 - 22 BISHOPSGATE, CITY OF LONDON

Lead Contractor: Multiplex

BIM Consultant: Freeform

Complex construction logistics and health & safety planning requirements for the 62-storey commercial tower, located at the centre of London's financial district, resulted in one of the most fully-realised 4D BIM models in existence.

Currently under construction, for client AXA Real Estate and Lipton Rogers Developments, the project has limited site access and features a deep triple basement, 57 lifts and complex interfaces with existing structure.

A fully federated 3D BIM model, produced by Multiplex and structural engineer WSP, was expanded by London-based 4D consultancy Freeform, to include features such as site escape routes, signage, hoarding lines, access gates, pit lanes, tower cranes, temporary site staircases, and edge protection details.

4D BIM modelling involves the intelligent linking of individual 3D CAD components or assemblies with time- or schedule-related information. By linking the 3D CAD model with project planning software Multiplex was able to scrub backwards or forwards in time through planned sequences of work to check for "clashes" and make adjustments. This helped the supply chain intuitively plan and interrogate sequences of work to ensure they were efficient and safe.

In addition, the 4D models were visualised by the team in virtual reality headsets to improve safety planning and communication. James Bowles, founder and director of Freeform, commented: "Multiplex saw the success of the technology on the Battersea Phase 2 project and wanted to push the boundaries even further, with a particular focus on immersive VR."

This enabled a level of spatial awareness and spatial understanding not possible when working in a 2D, or even in 3D on a screen, he added: ""VR makes things very immediate and obvious, you put the headset on and suddenly you are there, standing on the slab looking around the site and able to make informed decisions without the need to sift through a combination of drawings, a Gantt chart and a logistics plan."

Users were able to navigate and interact with the model, either at 1:20 scale, or in first person at 1:1 scale, using a pair of handheld controllers. Virtual tools were used to drag and drop logistics objects from a library into a scene, including tower cranes, excavators, skips and scaffolding.

According to Bowles, planning logistics between 6 and 12 months in advance of the work resulted in various sequence adjustments and a more secure safety plan with a level of detail only previously possible when work was starting on site.

6.3 CASE 3 - CURZON BUILDING, BIRMINGHAM CITY UNIVERSITY

Client: Birmingham City University

Lead Contractor: Willmott Dixon

Lead Architect: Associated Architects

The £46.2m project is intended to function as a "front door" and student hub for the campus and forms a key element of Birmingham City University's (BCU) expansion around City Park.

It comprises two buildings: a large two storey block, featuring a library, catering, student services, a student's union, connected to a Grade II-listed pub; and two wings of five- and six- storey accommodation linked by a central atrium, housing the faculties of Business, Law and Social Sciences, and Arts, Design and Media, and the University Directorate.

The project was the first to fully road test BCU's BIM ambitions as a client and integrates lessons learnt on the previous Parkside Building, the first ever project carried out by the University in BIM.

David Simpson, associate and BIM manager at Associated Architects, explains: "We evolved the Employer's Information Requirements (EIRs) and consolidated every parameter BCU wanted in its models for facilities management, going through a strict process of agreeing who should input what data into what part of a model when and how."

The client required a comprehensive set of FM deliverables in BIM, for which a bespoke schedule was developed, referred to as an Asset Information Matrix, specifying what information should be attached to every BIM object in the model.

Associated Architects coordinated 3D models, produced by M&E consultant Hoare Lea, structural and civils consultant White Young Green and landscape architect Atkins.

Willmott Dixon subsequently assumed the role of BIM Manager, post contract-award, when the scope was expanded to include the coordination of models and data produced by M&E contractor NG Bailey, novated consultants and all subcontractors.

The clash detection process was streamlined, exporting Revit models to cloud-based collaboration software to enable anyone on the project team to view them via an internet browser.

Simpson commented: "People sometimes joined the session remotely, everyone was viewing model and commenting on the model in real time, they could instantly see other people's comments and respond to them."

Around a dozen clashes were picked up, a process estimated to save Willmott Dixon about £10,000-£30,000 per clash in onsite remedial work, depending on the severity.

The contractor deployed iPads onsite, to access BIM models for snagging and onsite checking processes. Post-handover, iPads are being used by the FM team to scan barcodes and pull up 3D BIM models for specific rooms.

Touching on any object in the model displays embedded data, such as original design information, tasks, checklists, and links to relevant drawings. In addition, they provide the client with a complete record of every issue picked up during construction and how it was rectified.

The requirement for BIM as an FM deliverable placed a strong emphasis on the accuracy of 3D geometric models. A laser point cloud survey of the entire building was carried out at several points during construction: before floors and ceilings were installed, to map all voids, and post-completion. These were used to audit and update the accuracy of the original 3D models.

Accuracy was further improved by incorporating numerous photos of every room, including service runs concealed under ceilings, to help the FM team check the location of hidden services before they disturbing anything.

The extension to the Curzon Building, Curzon part B, is currently underway and features a number of BIM enhancements, such as a fully realised landscape model and more detailed 3D structural models from steel fabrication suppliers.