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Guidelines for BIM Information
Management at Design Stage

Giulia Terrosi

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Universidade do Minho
Escola de Engenharia

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BIM A+ European Master in Building Information Modelling

Master Dissertation
European Master in Building Information Modelling

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Giulia Ferrari

RESUMO

Diretrizes para a Gestão da Informação BIM na fase de Projeto

Para o *Building Information Modelling* (BIM) a Gestão da Informação representa qualidade e eficiência na recuperação, armazenamento, utilização e partilha da informação ao longo do ciclo de vida do projeto.

O planeamento detalhado, a definição dos papéis e responsabilidades, a avaliação das capacidades, e a declaração de requisitos devem ser estabelecidos desde o início do projeto para se conseguir uma gestão eficaz da informação de todo o processo. Contudo, mesmo que muitas empresas estejam a utilizar ferramentas BIM, muitas delas ainda não implementaram processos de informação normalizados.

Este trabalho criou um enquadramento para apoiar as empresas na gestão do BIM, especificamente durante a fase de projeto e levá-las a uma gestão estruturada da informação gerada durante esta fase preparando a sua passagem para as fases subsequentes.

Para tal, foi realizada uma pesquisa aprofundada sobre artigos publicados, guias e Normas aplicáveis para reunir as melhores práticas nesta área e propor diretrizes para apoiar uma adoção estruturada do BIM no projeto de uma empresa. Foi criado um fluxo de trabalho específico baseado na metodologia de *Integrated Project Delivery* para apoiar empresas na adoção do BIM. A partir daí, foram propostas várias ferramentas para ajudar o BIM Manager a estabelecer protocolos durante a fase de conceção do projeto. O quadro proposto poderia apoiar as empresas na avaliação e seleção das capacidades dos membros da equipa certa, na recolha eficiente de requisitos de informação, na elaboração de um Plano de Execução BIM adequado e na avaliação das plataformas comuns de dados CDE.

Este trabalho foi desenvolvido em colaboração com uma empresa de consultoria BIM, permitindo a validação paralela deste fluxo de trabalho e documentos ao longo de todo o processo. Estas ferramentas e o fluxo de trabalho concebido destinam-se a ajudar as empresas a acelerar os seus processos BIM, fomentar a colaboração entre todos os interessados, assegurando uma melhor gestão da informação, contribuindo assim para a qualidade dos resultados e desempenho geral da organização.

Palavras chave: (BIM, Gestão da Informação, Fase de projeto, Fluxo de Trabalho, Funções BIM)

ABSTRACT

Information Management in *Building Information Modelling* (BIM) deals with the quality and efficiency on the retrieval, storage, use and sharing of information throughout the project lifecycle.

The detailed planning, definition of roles and responsibilities, assessment of capabilities, and stating requirements should be established since the very beginning of the project to achieve an effective management of the information of the whole process. However, even if many companies are using BIM tools, lots of them have still not implemented standardised information processes.

This work created a framework to support companies in BIM projects, specifically during the Design Stage, to lead them to a structured management of the information generated during this stage and to prepare its handover.

To do so, in-depth research was conducted on published papers and articles, BIM guides and applicable Standards to gather the best practices in the field and propose guidelines to support a structured BIM adoption in a company´s project. It was created a specific workflow based on the *Integrated Project Delivery* methodology to support companies in BIM adoption. From there, several tools were proposed to assist the BIM Manager in establishing protocols during the project Design Stage. The proposed framework may be used to support companies in assessing and selecting the right team members capabilities, in collecting information requirements efficiently, in stablishing a proper BIM Execution Plan and evaluating CDE platforms.

This work was developed in collaboration with a BIM consulting company, allowing for a parallel validation process of this workflow and documents throughout the way.

These tools and the designed workflow are intended to help companies to accelerate their BIM processes, foster collaboration between all the stakeholders, assuring enhanced information management and therefore contributing to the quality of the output and general performance of the organisation.

Keywords: (BIM, Information Management, Design Stage, Workflow, BIM Roles)

ABSTRACT

Linee guida per la gestione delle informazioni in BIM nella fase di progetto

La gestione delle informazioni all'interno del *Building Information Modelling* (BIM) si basa sull'efficienza nel recupero, conservazione uso e condivisione delle informazioni attraverso l'intero svolgimento di un progetto.

Al fine di ottenere un'efficace gestione delle informazioni dell'intero processo, è necessario stabilire fin dal principio del progetto stesso un piano d'azione dettagliato, fissare i ruoli e i loro compiti, valutare ed asseverarne le competenze ed esplicarne i requisiti richiesti. Tuttavia, nonostante molte compagnie utilizzino già molti strumenti del BIM, mancano ancora di processi standardizzati per la gestione delle informazioni da esso generate e in esso contenute.

Lo scopo di questo lavoro è stato quello di creare di una struttura di supporto alle compagnie nella gestione dei progetti in BIM, nello specifico riguardo alla fase della progettazione e guidarle verso una gestione organizzata delle informazioni generate nel corso di questa fase e nella preparazione del passaggio di consegna di queste per la fase successiva.

Al fine di conseguire ciò, è stata eseguita un'accurata ricerca attraverso la consultazione di articoli e saggi pubblicati, manuali sul BIM e Standard vigenti al fine di acquisire le migliori tecniche e proporre delle linee guida che siano di supporto all'introduzione del BIM in un progetto da parte di una compagnia. Allo stesso scopo, è stato sviluppato uno specifico flusso di lavoro da seguire basato sulla metodologia dell'*Integrated Project Delivery*. In aggiunta sono stati sviluppati e proposti altri strumenti per agevolare il lavoro del BIM Manager nello stabilire protocolli per la fase di progettazione. Allo stesso tempo, la struttura di lavoro proposta, può anche avere la funzione di aiutare le compagnie nella valutazione e selezione dei più adatti componenti di un team di lavoro e delle loro competenze, di assisterle in un efficace reperimento delle informazioni necessarie, nella realizzazione di un adeguato 'BIM Execution Plan' e nella valutazione delle piattaforme per il CDE.

Questo lavoro è stato sviluppato in collaborazione con una compagnia di consulenza per il BIM, permettendo una convalidazione in parallelo del flusso di lavoro sviluppato e i documenti a supporto di esso durante tutto il periodo di lavoro.

Lo scopo della creazione del flusso di lavoro e degli strumenti a suo supporto è quello di aiutare le compagnie ad accelerare i loro processi nell'utilizzo del BIM, promuovere la collaborazione tra i soggetti interessati, assicurare l'ottimizzazione della gestione delle informazioni e, conseguentemente, contribuire alla qualità dei risultati e le generali prestazioni dell'organizzazione.

Keywords: (BIM, Gestione delle Informazioni, Fase della Progettazione, Flusso di Lavoro, Ruoli del BIM)

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1. INTRODUCTION

Over the last three decades, the introduction and implementation of Building Information Modelling (BIM) into processes with the support of technological tools has influenced and revolutionised the Engineering, Architecture and Construction (EAC) industry, introducing new approaches to the Design Stage. It has, furthermore, established new types of collaboration among stakeholders, from the very first stages of the project until the end of its lifecycle (Sacks et al., 2018). It has been proven that BIM tools and BIM workflows significantly increase design productivity, reduce construction waste, and improve connectivity in facility operations. 'To achieve such benefits, firstly, the model-based deliverables need to be clearly specified by the owner/client and, secondly, they have to be delivered by supply chain players according to the agreed-upon requirements' (Succar et al., 2016). Information management, therefore, becomes one of the central focuses of BIM processes.

It is impossible to define a unique workflow that can be adapted to each and every project. Each country or company is different, therefore, every single project needs to be considered for its own specificities. Nevertheless, some steps are fundamental in all cases, such as to define roles and responsibilities, to understand information requirements and to develop a plan of action for BIM implementation. The aim of these procedures is to clarify roles and responsibilities that all parties involved in the project will have to follow throughout the project lifecycle. Unfortunately, many improper definitions of Information Requirements (IR) can still be found all across literature. The reasons for this – in addition to the lack of knowledge of the BIM method – is the gap in usage maturity of already skilled users, especially with respect to standards and regulations (Jallow et al., 2008). The BIM Execution Plans (BEP) – which standardise the roles and responsibilities of all the stakeholders, the exchange of information and the correlated level of detail/development/information, the BIM uses and goals, and the Model quality assurance – are often impractical and quickly becomes obsolete – or at least undervalued (Donato et al., 2018). A plethora of documents, papers and essays have been elaborated on the subject, but the study of the problems that could have led to this situation is still at an initial level of development.

1.1. Objectives

This work intends to provide guidelines for BIM implementation and Information Management within a company during the Design Stage. In order to do that it is required to gather all the disperse information and best practices and compile them into a simplified guide that may be useful to the professional community in its entirety, especially to stakeholders involved in the Design Stage of building projects.

In order to accomplish this main objective, it is required to identify the roles and their responsibilities of the stakeholders involved in the BIM Design Stage, establish a comprehensive workflow and the expected deliverables along this process.

It may also be necessary to create document templates to help the BIM Manager and the designers to gather the project requirements and to produce specific tools to support the stakeholders along the process.

1.2. Research Methodology

This work was produced as a response to a real problem, faced by many professionals and particularly validated on an international BIM consulting company: *BIMMS -BIM Management Solutions*. Even though the company is currently working as a high-level profile in the BIM modelling business, they are finding difficulties in exchanging information among the processes of the project. Despite there being multiple sources of information on the issue, the company has required a more custom-fit process.

The research was based on previously published works that led to the creation of a guide that anyone – company members and clients/owners alike – could quickly consult and understand, by means of a simplified template.

Finally, with the development of a workflow with related templates and matrixes, this work was presented to the company for validation.

This research was conducted in close link with the dissertation entitled 'Information management workflow for the construction and operation phases on a BIM process', by Fontana (2020). The purpose was to do a complementary work by splitting the BIM process in two phases – design and construction.

1.3. Outline

It is worth reminding that this dissertation's purpose is to be a guide for the implementation of BIM Information Management workflow in the Design Stage and in the development of the related documents, thus supporting the BIMMS firm employees familiarizing with the BIM processes. For this reason, a handbook format was adopted, so as to facilitate internal use. Each chapter starts with a literature review and an analysis of a specific topic of the Design Stage, followed by the author's contribution and assessment. The structure of the dissertation is explained in Figure 1.

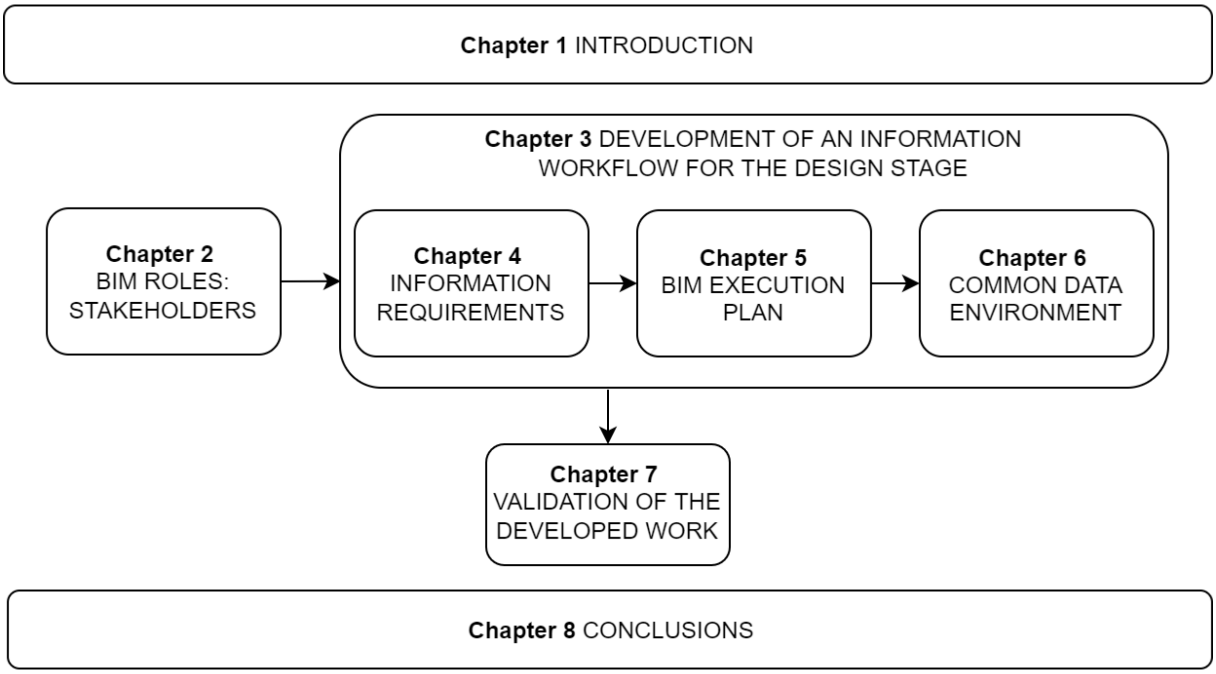

Figure 1 – Dissertation Structure

As shown, this dissertation is composed by eight chapters. This introductory chapter – **Chapter 1** – gives a general overview of the current situation of BIM adoption, identifies problems and proposes research objectives and solutions.

Chapter 2 investigates on **stakeholders** and their responsibilities accompanied by research on BIM maturity levels needed for each process. It also presents a summary table containing roles, its definition and the required competencies. In the end, a created matrix is presented to support the employee evaluation.

Chapter 3 introduces the **Information workflow**, designed to manage the company's project during the Design Stage, with a particular focus on the role of the stakeholders, their requirements and the deliverables that have to be produced.

Chapter 4 investigates the importance of **Information Requirements** in the BIM process, especially how the client should write them and which sections it should consist of. Four main Standards (USA, UK, International and Italian) are analysed and compared; a simplified Employer IR template is then proposed.

Chapter 5 introduces the importance of the **BIM Execution Plan** and how it should be presented. Like in the former chapter, it presents an analysis of the four standards (USA, UK, International and Italian) together with a final comparison and development of a simplified BEP template.

Chapter 6 presents the CDE requirements, benefits and core structure according to the Standards. A CDE evaluation matrix was developed to help the company select the most suitable platform according to the project’s needs.

Chapter 7 analyses the study case given by the company and contains the validation of the proposed information management workflow.

Chapter 8 contains the final considerations, mentioning the difficulties encountered during the process and proposing recommendations for further studies.

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2. BIM ROLES: STAKEHOLDERS

This chapter investigates the importance of the stakeholders, their responsibilities, and how traditional roles have changed after BIM adoption. Traditional and BIM specialised roles are explained namely their skills and expertise. However, in the competency matrix development, traditional and new roles overlap. It is indeed common that a traditional role holder in the AECO industry obtains a BIM specialisation as well. Finally, a BIM Competencies matrix and a Project's team members maturity level assessment matrix are proposed as a contribution to the company.

2.1. Literature Review

Successful projects depend on stakeholders' satisfaction. A stakeholder is a person who is involved in the construction and/or has an interest in its success. As BIM adoption rate increases, it begins to become evident that it is not all about software implementation and technology solutions; vast change in management and processes are also needed. In order to establish a process, it is necessary to identify the actors involved. BIM methodology introduces other professional figures to the current project workflow, at all stages. In this section, the roles and responsibilities involved in the entire Design Stage will be considered. Traditional actors are maintained, while newly BIM specialised figures are introduced. BIM adoption, in fact, affects all people involved in the project, changing their relationship and requesting a higher degree of interaction and interconnection. BIM methodology requires shared decision-making and cooperation among all actors since the very beginning of the project.

2.1.1. Roles and responsibilities definition of the stakeholders

Many handbooks, guidelines and manuals explore the BIM processes. However, in this work it was identified and described these newly-formed roles, which could change as quickly as processes themselves evolve. It also has to be mentioned that BIM specialists' roles need to be clear and precisely defined. At the current stage, countries have their own definition and description of roles and responsibilities; besides, companies' job descriptions do not always match the country's definition of the requested type of function. This lack of clarity is reflected in the reviewed literature: Barison and Santos (2010) listed up to 40 different BIM-related roles and Uhm et al. (2017) found 35 different BIM-related job descriptions. The research shows how the definition of BIM specialists is indeed ambiguous and suggests the necessity of a newfound clearness for BIM roles in organisation and project terminology (Davies et al., 2017).

This shortcoming explains why is it important that governments have a role in BIM adoption and implementation. Research demonstrated that countries where the government decided to take the lead, adopting and promoting BIM implementation – such as Finland, Norway, the UK, the Netherlands, Sweden, and Denmark – now register a BIM adoption and promotion rate higher than those of countries that did not. In fact, it seems that when the public sector is the key driver of BIM adoption, companies need to take fewer actions to follow the government recommendation (Travaglini et al., 2014).

However, it is worth noting how countries have so far devised different methods of BIM adoption, with their own different standards and processes. In the 2014 amendment, the EU Public Procurement Directive (EUPPD) encouraged all member states to recommend BIM adoption in publicly funded construction projects, thus leaving freedom of choice on the matter. The next challenge is to unify all the definitions found in manuals, guides, handbooks, and job description under one, cohesive set of rules. This task will help clarify who the players really are and what their related responsibilities will be.

Travaglini et al. (2014) classifies stakeholders according to their connection with a set project (Table 1). Internal stakeholders (formally connected) and external stakeholders (affected in some way). Then, those categories are subdivided again: the internal in ‘demand’ and ‘supply’; the external in ‘private’ and ‘public’.

Table 1 – Internal and external stakeholders classification - adapted from (Travaglini et al., 2014)

Internal stakeholders		External stakeholders	
Demand side	**Supply side**	**Private**	**Public**
Client	Architects	Environmentalist	Local authorities
Financer	Engineers	Insurance companies	National authorities
	Principal contractors	Researchers	Government
	Subcontractors	Educational institutions	
	Operators	Trade and industry	
	Consultant	Social organisations	
	Fabricators	Media	
	Facility Manager		
	BIM manager		
	PM		
	Developers		

In a second analysis, Travaglini et al. (2014) identifies a matrix based on the variable of power and interest (Figure 2). This matrix allocates stakeholders into four groups.

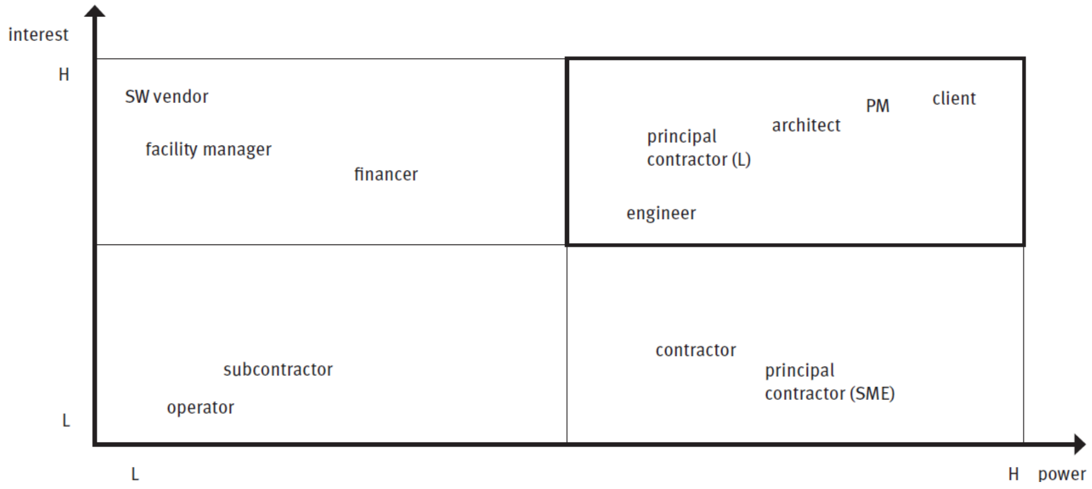


Figure 2 – Interest/power Matrix (Travaglini et al., 2014)

The matrix shows how the main stakeholders of a project are the client – in a primary position –, the project manager, the architect, the main Contractor, and the engineer. The purpose of this research being to evaluate the *main* stakeholders in BIM adoption, it does not take into account BIM specialists.

Prior to the investigation of the new roles, a characterisation of the current ones must be performed including how they have evolved.

Client/Owner

The client is the person or organisation who has the highest interest – and power – in the project, due to the expected benefits they will draw from it. They are also responsible for the financial costs. With the introduction of BIM, clients are now in charge of determining their expectations and requirements beforehand by codifying the information in a document. They also summarise the roles and responsibilities for managing BIM data for the facilities and asset management. In order to maximise the use of BIM, the client should specify its use and deliverables to meet their expectations. With the implementation of the Integrated Project Delivery (IPD) method, the single client-contractor or client-architect relationship does not exist anymore. Client, architect, main Contractor, project manager, consultant, and facility manager, are working as a team since the beginning of the project. This integrated approach requires an open cooperation from both sides of demand and supply (cfr. before), and a consequent mind-set change is needed. In this new scenario, in fact, the client has to develop information management skills, hence understanding the process and establishing the deliverables.

Architect – Traditional role

The architect is the leading project designer and the one who takes care of meeting the client requests since the early concept. Despite the use of BIM might end up quickening and ameliorating the work in many ways and even improving the level of information, interoperability, and collaboration with other disciplines, there are still only a few tools that can support the concept design. During this stage, the architect is still to express his/her creativity mostly using pen and paper or their technological cousins: touch-screen pen and tablet. Some software like Sketchup and Rhinoceros might help, thanks to the use of NURBS or masses. Opinions on these tools are contrasting, and the issue shall require further study.

With the advent of BIM processes, architects have the final say on the design and they are in charge of exploring different layouts and materials, taking into account the final user's wishes and the facility management and operational phases according to the IPD. They are also responsible for the construction-level information, the detection of clashes and for the quality control of the architectural model, as well as for the collaboration and synchronisation with other process players: civil engineers, structural engineers and MEP engineers. They finally deliver construction documents and coordinate other players.

Engineers – Traditional role

Engineers could be classified as: structural, civil, mechanical, electrical and plumbing (MEP), and energy (the latter being in charge of testing the building energy performance using tools as Green Building Studio or Energy Plus among many others). Each of these players has the responsibility to develop a model according to the required level of detail, as well as to superintend the model quality control and clash detection. Engineers are in charge of exploring different solutions according to architectural design and project costs. They have to coordinate with the architect and to harmonise the model: any time the design changes, they transpose the change across all models. They finally have to prepare and deliver construction drawings according to the EIR.

Project Manager – Traditional role

The PM is ultimately responsible for the entire project. He is the leader and has to make sure the entire team meet the client's requests, according to the specifications. He is in direct contact with the client, the architect, the consultant, and the facility manager. The PM may be an architect, but it is not a requirement. In case this role is played by a third party, they have the duty of establishing processes so as to coordinate all teams' information management and quality control. They have to be aware of the objectives, keep the costs under control, meet the deadlines and quality standards, and finally interface with the Public Administration.

Contractors – Traditional role

The Contractor is the person responsible for the proper construction and has a contract with the client. Contractors can be main contractors or subcontractors, according to the EIR and the BEP. In the IPD, the Contractor is first-handly involved in the process since the early stages, with the duty of identifying any design issue using a digital model and some other tools – e.g. Navisworks or others – before the construction begins. Using these tools, the Contractor has the ability to simulate the construction phase, figuring out the costs, getting a sense of the outcome, quantity, and quality of the project. Thanks to the implementation of these digital twins, contractors may organise the construction site and appraise the number of workers needed for each day and in each phase, minimising the costs and the effort.

Quantity Surveyors – Traditional role

The QS is the person responsible for managing and controlling the costs of the project and the contractual administration. In the BIM process, they are in charge of using digital twins in order to extract visual and schedule-based information and eliminate usual errors such as ordering the wrong quantity of material or causing a delay in the construction site – all things that may end up in a general soaring of costs. They can use tools such as Vico, which can extract information directly from the model and create a diagram. The QS work depends entirely on the accuracy of the model; therefore, they need to coordinate with the architect and the engineers for the development of said model.

Facility Manager – Traditional role

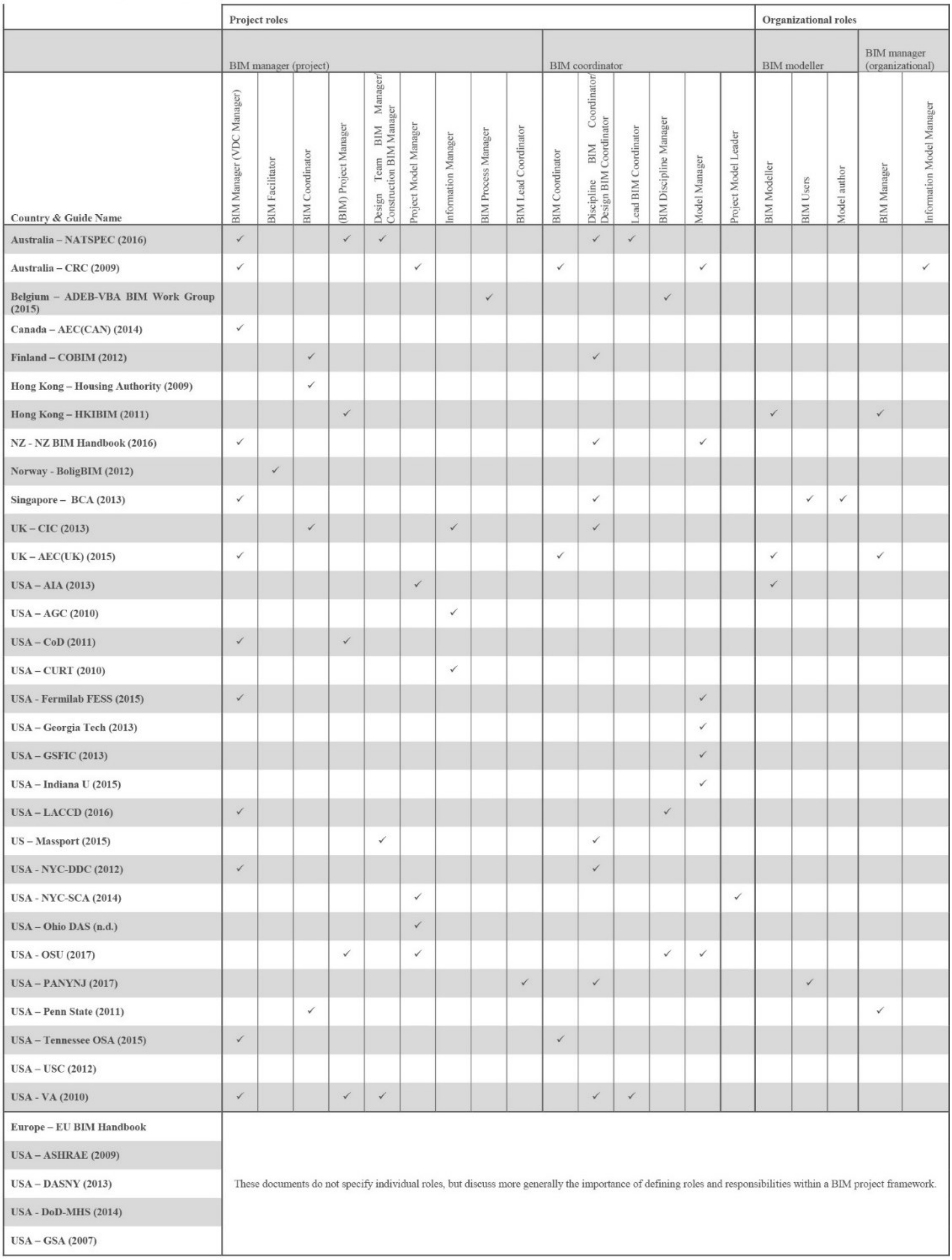
The role of the FM in a BIM-based project is connected to the design concept of the project and to its planning. It has been proved by research (Ashworth et al., 2016) how the simple act of involving an FM from the early stages – even including them in the EIR – has many perks for the final success of the project. A proficient space design, both for the movement of people and equipment, as well as a logistic and well-planned use of the assets, will help in the long run, reducing requests for changes and cutting costs for the entire building life cycle, thanks to the post-occupancy evaluation. Their role is fundamental for the assets of the building and its future maintenance.

Information Manager – Traditional role

Although the figure of the Information Manager is well defined in the PAS1192 documents and in the CIC, and their presence is considered part of the BIM Manager crew, this role may not be BIM specialists related. This player is in fact employed by the client to overview the entire information requirements: they are, therefore, not involved in the design functions, such as quality control or clash detection due by the model coordination. Before the advent of the BIM, the Information Manager's role was to establish processes, protocols and information exchange. It is easy to understand how this role could perfectly fit inside the process of a BIM-based project.

Many BIM handbooks, guidelines and articles tried to identify the new roles born after the advent of the BIM and what the relationships between them might be. All of them agreed that open collaboration and shared decision-making between all the characters involved in the project – traditional ones and new ones – are key. The challenge, here, is to unify all different role names and tasks under a handful of leading roles. Davies (2017) made a compelling work on the matter in her PhD dissertation, analysing 36 different guidelines from different countries in creating a comparison table (Table 2). She unified all the roles and job description she found into three main categories: BIM Manager, BIM Coordinator and BIM Modeller. She also split them into 'project roles' and 'organisational roles', duplicating the BIM Manager into two different positions: project and organisational.

Table 2 – Role categories identified in BIM guides (Davies et al., 2017)



	Project roles															Organizational roles				
	BIM manager (project)									BIM coordinator						BIM modeller			BIM manager (organizational)	
Country & Guide Name	BIM Manager (VDC Manager)	BIM Facilitator	BIM Coordinator	(BIM) Project Manager	Design Team BIM Manager/ Construction BIM Manager	Project Model Manager	Information Manager	BIM Process Manager	BIM Lead Coordinator	BIM Coordinator	Discipline BIM Coordinator/ Design BIM Coordinator	Lead BIM Coordinator	BIM Discipline Manager	Model Manager	Project Model Leader	BIM Modeller	BIM Users	Model author	BIM Manager	Information Model Manager
Australia – NATSPEC (2016)	✓			✓	✓						✓	✓								
Australia – CRC (2009)	✓					✓				✓				✓						✓
Belgium – ADEB-VBA BIM Work Group (2015)								✓					✓							
Canada – AEC(CAN) (2014)	✓																			
Finland – COBIM (2012)			✓								✓									
Hong Kong – Housing Authority (2009)			✓																	
Hong Kong – HKIBIM (2011)				✓												✓			✓	
NZ - NZ BIM Handbook (2016)	✓										✓			✓						
Norway - BoligBIM (2012)		✓																		
Singapore – BCA (2013)	✓										✓						✓	✓		
UK – CIC (2013)			✓				✓				✓									
UK – AEC(UK) (2015)	✓									✓						✓			✓	
USA – AIA (2013)						✓										✓				
USA – AGC (2010)							✓													
USA – CoD (2011)	✓			✓																
USA – CURT (2010)							✓													
USA - Fermilab FESS (2015)	✓													✓						
USA – Georgia Tech (2013)														✓						
USA – GSFIC (2013)														✓						
USA – Indiana U (2015)														✓						
USA – LACCD (2016)	✓												✓							
US – Massport (2015)					✓						✓									
USA - NYC-DDC (2012)	✓										✓									
USA - NYC-SCA (2014)						✓									✓					
USA – Ohio DAS (n.d.)						✓														
USA - OSU (2017)				✓		✓							✓	✓						
USA – PANYNJ (2017)									✓		✓						✓			
USA – Penn State (2011)			✓																✓	
USA – Tennessee OSA (2015)	✓									✓										
USA – USC (2012)																				
USA - VA (2010)	✓			✓	✓						✓	✓								
Europe – EU BIM Handbook	These documents do not specify individual roles, but discuss more generally the importance of defining roles and responsibilities within a BIM project framework.																			
USA – ASHRAE (2009)																				
USA – DASNY (2013)																				
USA - DoD-MHS (2014)																				
USA – GSA (2007)																				

BIM Manager – project or organisational role

BIM Managers are responsible for the information flow. They are in charge of the whole project: schedules, collaborations, processes. During the early steps of the project (Strategic Definition, Preparation and Brief), they supervise programming, coordinate the meetings between the stakeholders, and produce documents and minutes. The BIM Managers acts on behalf of the Client/Owner, compiling and delivering the EIR and the BEP. Throughout all the project lifecycle, they also settle and coordinate weekly or fortnightly meetings for the working groups specific to each project phase. As main coordinator of the information process, they also coordinate and supervise the BIM Coordinators' works and meetings. They establish protocols and assure the quality of the model and of the information within. Every week or two they need to run a Federated model clash detection and quality control, reporting issues to the BIM Coordinators (in case of large projects) or to the main designer. They finally need to coordinate and organise training for the teams, procurement of software, selection of authoring tools for the project (BEP) or the company. This could be handled by annual programmed training within the company or by specific training right before the beginning of the project.

The architect, in the capacity of lead designer, the Main Contractor, or even a third party can play this role. According to many handbooks, the BIM Manager reports to the Project Manager.

BIM Coordinator

This role is usually seen as secondary and put under the control of the BIM Manager. While the BIM Manager is responsible for the final Federated model, the BIM Coordinator manages and controls a single discipline team model: its quality, conformity to standards, and information exchange. The BIM Coordinator has to set team protocols and develop processes for the discipline team, enabling and improving collaboration. Every developed protocol aims at speeding up the process and making the information reusable for subsequent steps or new projects. A specifically BIM trained person ought to play this role, but in case of smaller projects or companies it could be carried out by the most experienced worker in the discipline team.

BIM Modeller

This role combines the ones of BIM Modeller, BIM User, and Model Author. A BIM Modeller is in charge of developing the model, producing the design documentation and quality check. It is an entry-level position, being held by people with 0-3 years' experience in modelling. After this level, the employee may choose the direction toward which orientate his or her career. They may become a BIM Specialist, keep working on models development (software implementation, coding and similar), or they might choose to head for information management, developing processes and coordinating teams.

BIM Consultant

They are external players that may be employed directly by the client, the company or the main Contractor. They are responsible for assisting the Employer on BIM adoption, protocols, standards, implementation, and processes. Generally, a BIM Consultant could work for a consultant company or being self-employed. These actors are deeply involved in the BIM world and have a solid background in both work and academics. Thanks to this dual experience, BIM Consultants are able to develop and settle processes and training, driving the company towards a correct BIM implementation.

2.1.2. Stakeholders BIM Profiles and BIM Maturity Level needed for each process

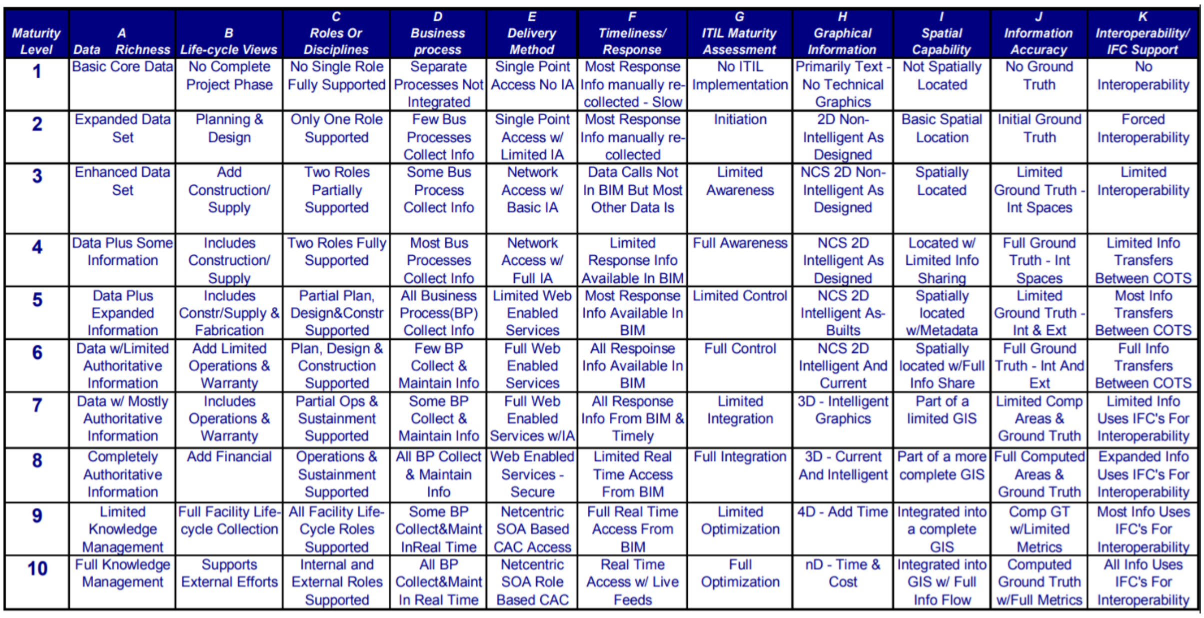
First of all, it is important to explain the difference between ‘BIM Capability – the ability to generate BIM deliverables and services – and BIM Maturity – the extent, depth, quality, predictability and repeatability of these BIM deliverables and services’ (BIM Think Space, 2009). When we speak of Maturity level, what it is meant is the ability of a person, a company, or a country to operate and exchange information among BIM process. It is challenging to find a specialised and unique BIM Capability and Maturity tool that can be used by both companies and external experts, as it seems quite impossible to create a suitable maturity matrix for the whole AECO industry. Many organisations and researchers have investigated these Maturity levels. In this work, the following will be taken into account:

- the US National Building Information Model Standard (NIBMS, 2007), with its Capability Maturity Model (CMM) and Interactive Capability Maturity Model (I-CMM);
- the British Standard Institution (BSI) PAS 1192 – 2:2013 (2013);
- the International Organization for Standardization (ISO 19650-1, 2018);
- the UK Construction Project Information Committee (CPIC, 2013) with its CPIx BIM Assessment Form;
- the BIM Capability by Bilal Succar (2009);
- the BIM Maturity Matrix (BIMMM) by Bilal Succar (2009).

The **National Institute of Buildings Science** (NIBS) developed standards on information exchange specific for each phase of the project, taking into consideration the stakeholders of the AECOOFM community (Architect, Engineer, Constructor, Operator, Owner, Facility Manager). In its first version – Part 1 (Table 3), it defines the **minimum** BIM and uses a Capability Maturity Model (CMM) to give the users a range of capabilities to evaluate the BIM maturity. The Tabular CMM matrix is a static table with 11 areas of interest in the x-axis – listed with no particular order – and 10 levels of maturity on the y-axis. The table's body gives the definitions of the different levels of maturity. And this is the point that led to dispute: not everybody agrees with these definitions or their interpretation.

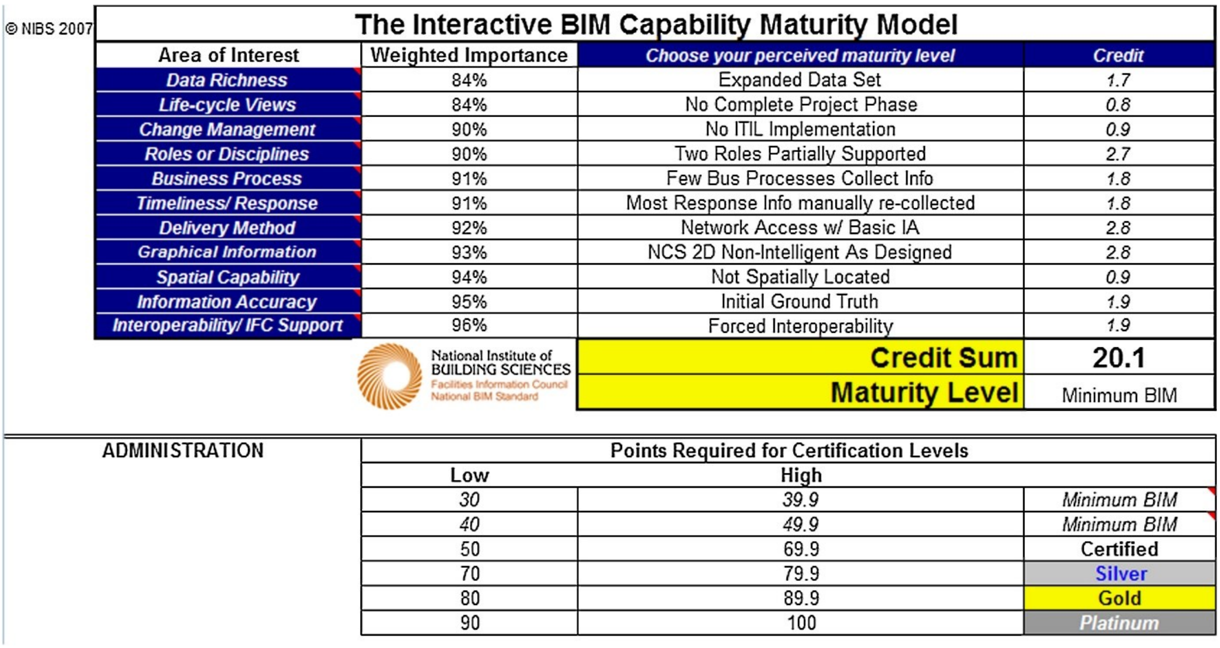
The **Interactive CMM** (I-CMM) is an Excel interactive multi-tab based on the CMM static table and – as the latter – uses a point-scoring scheme for each area of interest (Table 4). To achieve **minimum** BIM maturity, the project score has to be equivalent or superior to the minimum standard. This interactive version seems more user friendly than the previous one. Through a system of columns (which represent the area of interest in order of importance) and explanatory drop-down menus, users can self-evaluate the maturity level of their own BIM processes.

Table 3 – Tabular CMM matrix (NIBMS, 2007)



Maturity Level	A Data Richness	B Life-cycle Views	C Roles Or Disciplines	D Business process	E Delivery Method	F Timeliness/ Response	G ITIL Maturity Assessment	H Graphical Information	I Spatial Capability	J Information Accuracy	K Interoperability/ IFC Support
1	Basic Core Data	No Complete Project Phase	No Single Role Fully Supported	Separate Processes Not Integrated	Single Point Access No IA	Most Response Info manually re-collected - Slow	No ITIL Implementation	Primarily Text - No Technical Graphics	Not Spatially Located	No Ground Truth	No Interoperability
2	Expanded Data Set	Planning & Design	Only One Role Supported	Few Bus Processes Collect Info	Single Point Access w/ Limited IA	Most Response Info manually re-collected	Initiation	2D Non-Intelligent As Designed	Basic Spatial Location	Initial Ground Truth	Forced Interoperability
3	Enhanced Data Set	Add Construction/ Supply	Two Roles Partially Supported	Some Bus Process Collect Info	Network Access w/ Basic IA	Data Calls Not In BIM But Most Other Data Is	Limited Awareness	NCS 2D Non-Intelligent As Designed	Spatially Located	Limited Ground Truth - Int Spaces	Limited Interoperability
4	Data Plus Some Information	Includes Construction/ Supply	Two Roles Fully Supported	Most Bus Processes Collect Info	Network Access w/ Full IA	Limited Response Info Available In BIM	Full Awareness	NCS 2D Intelligent As Designed	Located w/ Limited Info Sharing	Full Ground Truth - Int Spaces	Limited Info Transfers Between COTS
5	Data Plus Expanded Information	Includes Constr/Supply & Fabrication	Partial Plan, Design&Constr Supported	All Business Process(BP) Collect Info	Limited Web Enabled Services	Most Response Info Available In BIM	Limited Control	NCS 2D Intelligent As-Builts	Spatially located w/Metadata	Limited Ground Truth - Int & Ext	Most Info Transfers Between COTS
6	Data w/Limited Authoritative Information	Add Limited Operations & Warranty	Plan, Design & Construction Supported	Few BP Collect & Maintain Info	Full Web Enabled Services	All Respoinse Info Available In BIM	Full Control	NCS 2D Intelligent And Current	Spatially located w/Full Info Share	Full Ground Truth - Int And Ext	Full Info Transfers Between COTS
7	Data w/ Mostly Authoritative Information	Includes Operations & Warranty	Partial Ops & Sustainment Supported	Some BP Collect & Maintain Info	Full Web Enabled Services w/IA	All Response Info From BIM & Timely	Limited Integration	3D - Intelligent Graphics	Part of a limited GIS	Limited Comp Areas & Ground Truth	Limited Info Uses IFC's For Interoperability
8	Completely Authoritative Information	Add Financial	Operations & Sustainment Supported	All BP Collect & Maintain Info	Web Enabled Services - Secure	Limited Real Time Access From BIM	Full Integration	3D - Current And Intelligent	Part of a more complete GIS	Full Computed Areas & Ground Truth	Expanded Info Uses IFC's For Interoperability
9	Limited Knowledge Management	Full Facility Life-cycle Collection	All Facility Life-Cycle Roles Supported	Some BP Collect&Maint InReal Time	Netcentric SOA Based CAC Access	Full Real Time Access From BIM	Limited Optimization	4D - Add Time	Integrated into a complete GIS	Comp GT w/Limited Metrics	Most Info Uses IFC's For Interoperability
10	Full Knowledge Management	Supports External Efforts	Internal and External Roles Supported	All BP Collect&Maint In Real Time	Netcentric SOA Role Based CAC	Real Time Access w/ Live Feeds	Full Optimization	nD - Time & Cost	Integrated into GIS w/ Full Info Flow	Computed Ground Truth w/Full Metrics	All Info Uses IFC's For Interoperability

Table 4 – Interactive CMM (I-CMM) (NIBMS, 2007)



© NIBS 2007

The Interactive BIM Capability Maturity Model

Area of Interest	Weighted Importance	Choose your perceived maturity level	Credit
Data Richness	84%	Expanded Data Set	1.7
Life-cycle Views	84%	No Complete Project Phase	0.8
Change Management	90%	No ITIL Implementation	0.9
Roles or Disciplines	90%	Two Roles Partially Supported	2.7
Business Process	91%	Few Bus Processes Collect Info	1.8
Timeliness/ Response	91%	Most Response Info manually re-collected	1.8
Delivery Method	92%	Network Access w/ Basic IA	2.8
Graphical Information	93%	NCS 2D Non-Intelligent As Designed	2.8
Spatial Capability	94%	Not Spatially Located	0.9
Information Accuracy	95%	Initial Ground Truth	1.9
Interoperability/ IFC Support	96%	Forced Interoperability	1.9
		Credit Sum	**20.1**
		Maturity Level	Minimum BIM

National Institute of BUILDING SCIENCES
Facilities Information Council
National BIM Standard

ADMINISTRATION

Points Required for Certification Levels

Low	High	
30	39.9	Minimum BIM
40	49.9	Minimum BIM
50	69.9	Certified
70	79.9	Silver
80	89.9	Gold
90	100	Platinum

This is as an internal tool to self-evaluate the Maturity level of a BIM project, to convert a case-by-case rating into an objective one. This method is focused on information management and does not see things from an architectural, engineering, or construction standpoint.

The **British Standard Institution** identifies four levels of BIM Maturity: from level 0 (CAD-based) to level 3 (iBIM based) (Figure 3).

In **level 0**, there is no collaboration between the stakeholders; drawings are shared as 2D images printed on paper.

In **level 1** 3D is used for the architectonical concept project, but documents are still shared in 2D and drawings are printed out for the construction site. There is no collaboration between the different areas: each one produces and keeps their own data. Drawings and documents are shared by e-mail and generally managed by the Contractor.

Level 2 is characterised by a collaborative work and all areas use 3D, federated models. Each stakeholder is able to export information at least in one of the most common exchange formats, namely IFC (Industry Foundation Class) or COBie (Construction Operations Building Information Exchange).

Level 3 is the most ambitious level to achieve. It is marked by a full collaboration between all the stakeholders and the areas are developed by means of an uniquely integrated model, stored in an integrated Common Data Environment (CDE). This is called 'Open BIM stage'. If a project reaches this level, it will be necessary to be particularly careful about data security and intellectual property rights.

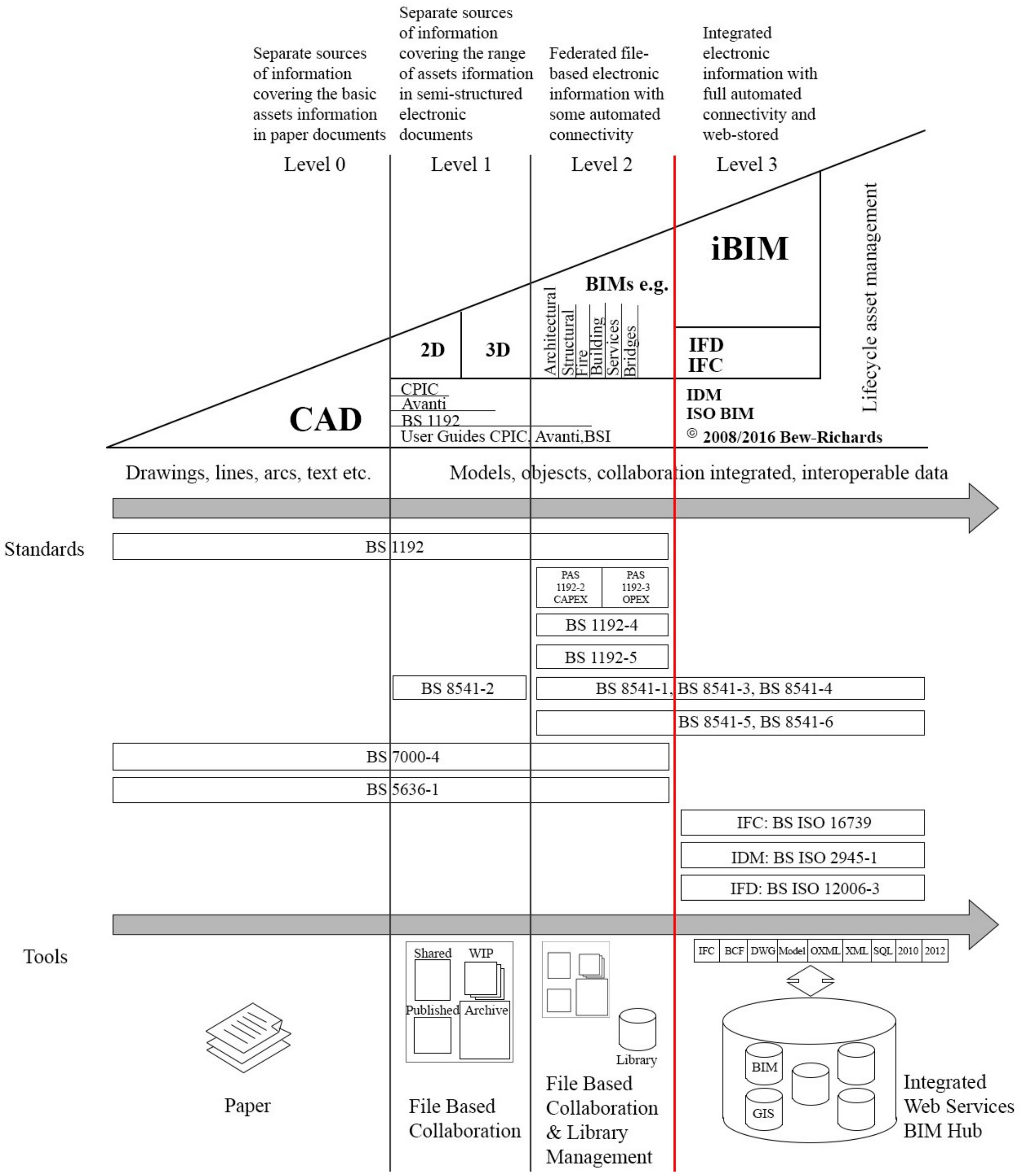


Figure 3 – BIM Maturity Levels – adapted from BIM Maturity level model by Bew & Richards (2008) (British Standards Institution, 2013)

The **ISO Standard 19650-1**:**2108,** based on British PAS 1192, lists three BIM maturity stages (Figure 4), associated with four layers: Standards, Technology, Information and Business. This Standard defines information management as dependent on the responsibility of each party to accomplish the overall project. The maturity stages explained in the figure are focused on standards development, improved forms of information management and advanced technology, to get the most benefits from the project. Despite ISO 19650 having 3 BIM stages, it is mostly applied to level 2 projects, where manual and automated information management coexist with the use of a federated model and each team delivers their own information model according to the project milestones.

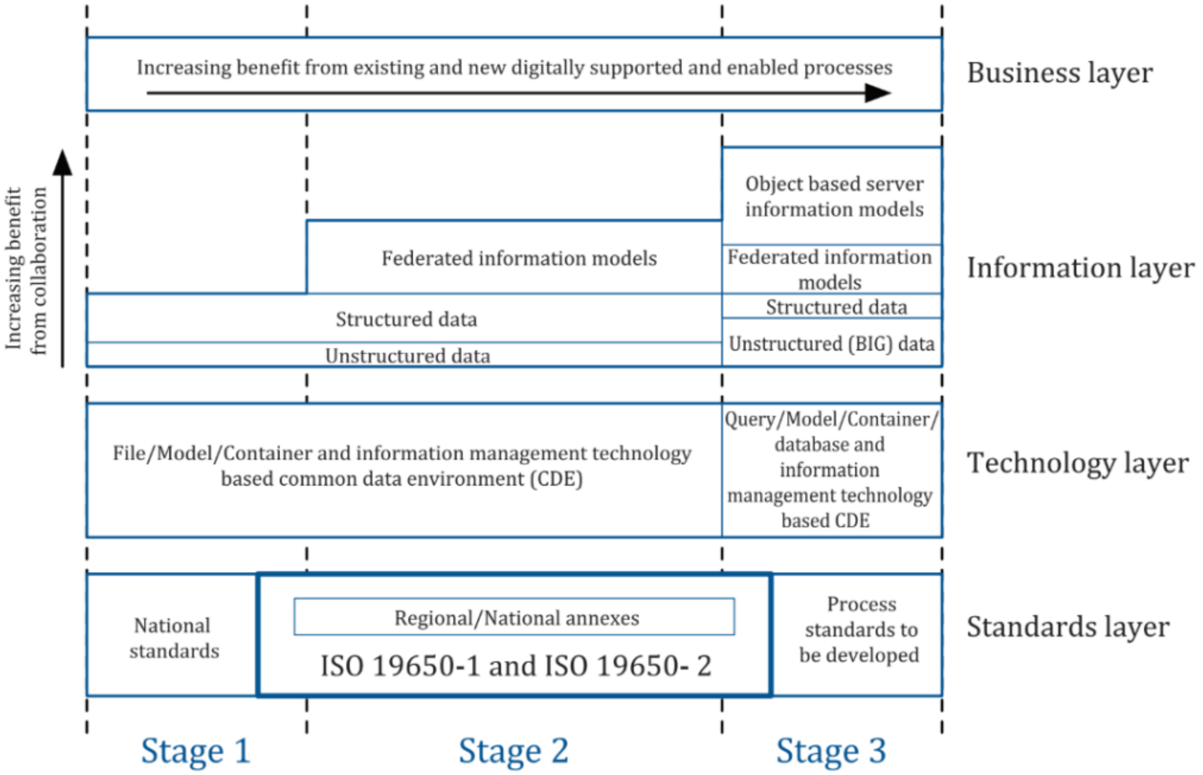
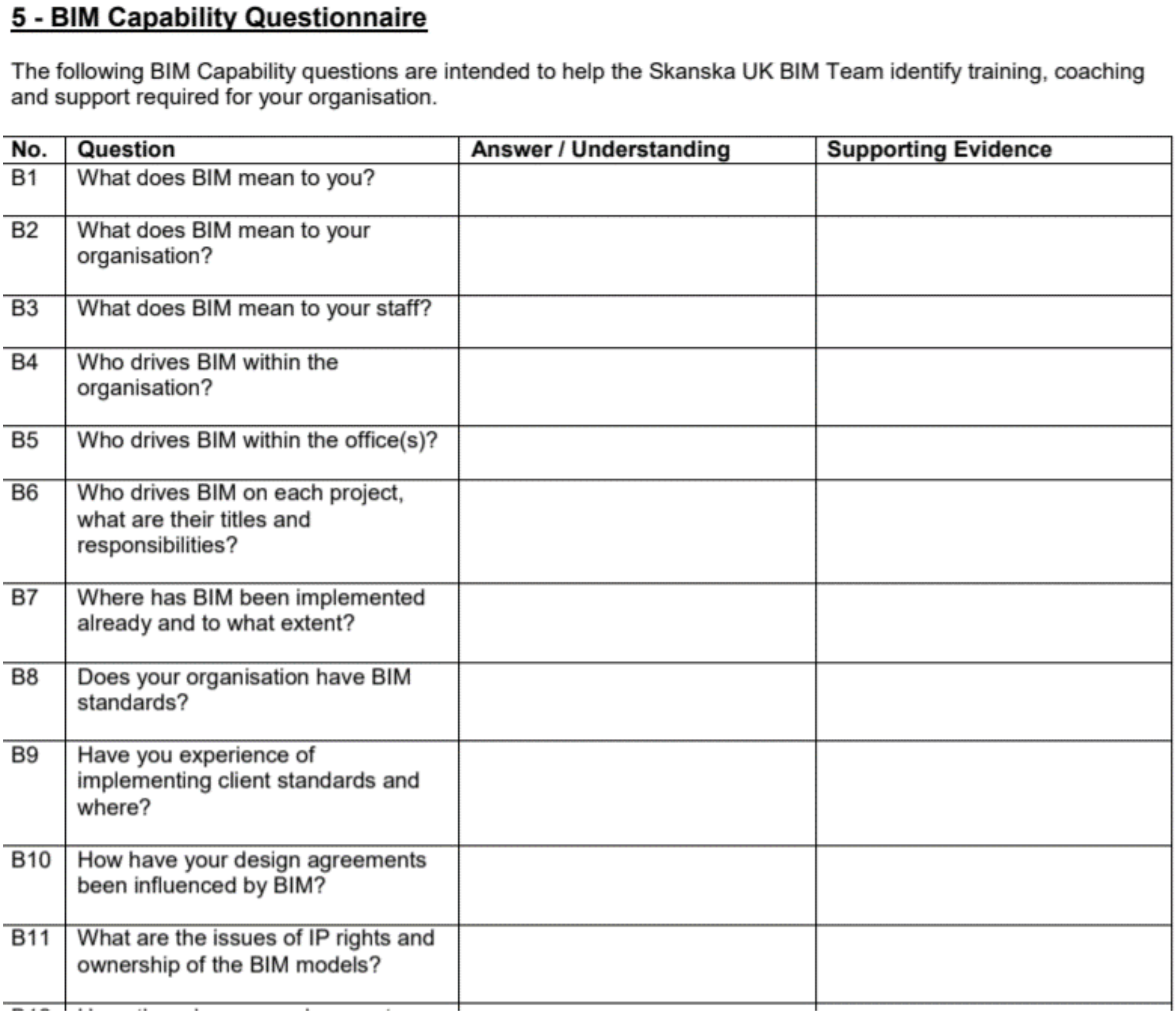


Figure 4 – BIM Maturity Stages (ISO 19650-1, 2018)

The CPIx BIM Assessment Form is a method designed to asses a project member's BIM competences and maturity (Table 5). It is divided into four sections. The first is about the exchange and quality of the data; the second divides the project in twelve areas and evaluates which of these could be supported by BIM and from which one the company and the project could benefit from; the third identifies three projects which could benefit from the BIM; and the fourth consists of a BIM Capability questionnaire made by 29 well-divided questions about BIM tools, processes and development. This questionnaire can be used to assess team members, but it requires quite a long time to be filled, read, and evaluated.

Table 5 – CPIx BIM Assessment Form (CPIC, 2013)



5 - BIM Capability Questionnaire

The following BIM Capability questions are intended to help the Skanska UK BIM Team identify training, coaching and support required for your organisation.

No.	Question	Answer / Understanding	Supporting Evidence
B1	What does BIM mean to you?		
B2	What does BIM mean to your organisation?		
B3	What does BIM mean to your staff?		
B4	Who drives BIM within the organisation?		
B5	Who drives BIM within the office(s)?		
B6	Who drives BIM on each project, what are their titles and responsibilities?		
B7	Where has BIM been implemented already and to what extent?		
B8	Does your organisation have BIM standards?		
B9	Have you experience of implementing client standards and where?		
B10	How have your design agreements been influenced by BIM?		
B11	What are the issues of IP rights and ownership of the BIM models?		

Bilal Succar (2009) defines a BIM Competency Set as a "*BIM Player's ability to satisfy a BIM Requirement or generate a BIM Deliverable… a hierarchical collection of individual competencies identified for BIM implementation and assessment*". He divides BIM capability into a total of five stages subdivided in: three stages of BIM maturity plus a pre-BIM status and the IPD process – which is considered to be the most desirable ones (Figure 5).

Pre-BIM status has only 2D drawings and documentation; even if a 3D model exists, the drawings are published as a 2D visualisation or as detail. The workflow is synchronous and the stakeholders do not actively collaborate.

At **BIM Stage 1** (Object-based Modelling) an object-based 3D parametric software is used, but we are still in single-disciplinary model territory; the stakeholder's collaboration is unidirectional, just like in the previous stages. Even if there are different 3D models included in the deliverables, 2D documentation and 3D visualisations are still used. A preliminary data export from the 3D model (windows/doors schedules) may appear.

In **BIM Stage 2** (Model-based Collaboration), different disciplinary actors start to collaborate with each other, exchanging models or parts of the model. The interchanging collaboration can take place using a native format of the same software, such as Revit Architecture and Revit Structure, or a common exchange format – e.g. IFC – among different software. The collaboration can take place between the same project phase or between two project phases, such as the Design-Design information exchange between the architectural and the structural model or the Design-Operations between architectural and facility maintenance models. However, while disciplines and roles start to cooperate, the stakeholders still communicate and work in asynchronous, as in the previous stages.

BIM Stage 3 (Network-based Integration). At this stage, 3D information models are created and shared collaboratively in a CDE, using native or common format to federate them. The information contained in the models allows for the creation of cost analysis, green policies, lean construction and facility operation analysis. Collaboration is now synchronous and the document-based information exchange is extracted from the models. This teamwork reduces the number of phases and processes, the duplication of information and the overall economic waste.

Integrated Project Delivery is the aimed stage of BIM, a combination of policies, technologies and processes. It is based on a real-time integrated model, where all disciplines are interdependent, and the collaboration is actively open. This stage was voluntarily left with a full, not well-defined, description to be more comprehensive for future BIM developments.

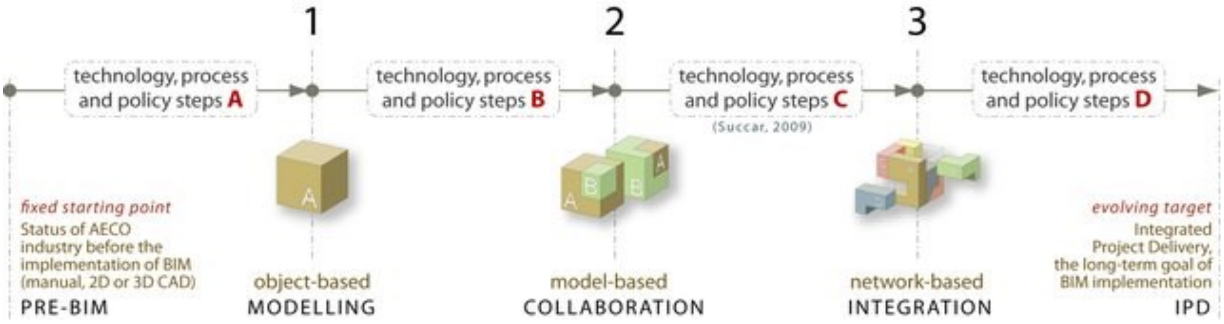


Figure 5 – BIM Capability stages (Succar, 2009)

In the following table were summarised BIM Maturity levels from different sources to compare and link them (Table 6).

Table 6 – BIM Maturity Levels Systems Comparison

	Maturity Level				
CCM	1 - 2	3 - 4	5 - 6	7 - 8	9 - 10
PAS 1192 – 2:2013	CAD		Level 1	Level 2	Level 3
ISO 19650-1			Stage 1	Stage 2	Stage 3
BIM Capability (Succar, 2009)	Pre-BIM	Stage1	Stage 2	Stage 3	IPD

2.2. Development of BIM Maturity Matrix for a company internal evaluation

As a result of this research, two matrixes were developed. The first one aims at assessing the desirable role competencies; the second one is to be used to appraise people competency for each project. In the literature review on roles, responsibilities and competencies a matrix able to express the importance of the role competency in BIM processes and at the same time able to clarify the skills of the role to be improved for the BIM development adoption was not found. It is paramount for a company to be able to determine the competencies of the team members, to understand if they are adequately composed and if they need to be changed before the work begins. To develop a matrix that can fill this gap, it was firstly necessary to understand which roles were on the market and to group them in categories (see section 2.1.1); secondly, it was researched and compared the studies on the matter, to better understand which was the best approach to the problem (see section 2.1.2). The use of a matrix seemed like a perfect solution to quickly and easily fill and manage a document.

Before the project starts the BIM Manager, on behalf of the Client, assesses the competencies of all team members. For that aim, a first matrix was created to clarify the role definition, supporting the BIM Manager to evaluate and choose the right person for each job. It was, in fact, developed listing the roles analysed before and giving a brief explanation of their responsibility. The last column shows a list of the competencies needed by each candidate to perfectly suit the role. In this produced table, traditional and BIM roles are both listed. Even if roles overlap – and, for example, the leading architect also functions as BIM Manager and another experienced one also functions as BIM Coordinator, as explained in sub-chapter 2.1.1 – they are kept distinguished nonetheless. This decision was made to have a better and more understandable description of the competencies required for each role (see Table 7)

Table 7 – BIM Competencies Matrix

Role	Role’s Responsibility	Expectable Role's Competencies
Client/Owner	Write a proper EIR	- Scope of work - Strategy - Organisation and Planning (set project deliverables, schedules) - Coordination - Open Collaboration (IPD) - Standardisation - LOD
Architect	Main designer - miss client's requirements	- Technical skills - Software skills - Coordination (IPD) - Communication - Quality Control
Engineer	Explore different solutions according to architectural design	- Technical skills - Software skills - Communication - Quality Control
Project Manager	Make sure the entire team will achieve the client's requests according to specifications	- Organisation and Planning - Coordination (IPD) - Communication - Strategy

Role	Role’s Responsibility	Expectable Role's Competencies
Contractor	Identify design issue before the construction phase starts	- Technical skills - Software skills - Coordination (IPD) - Information Modelling
Quantity Surveyor	Manage and control project costs and contractual administration	- Technical skills - Software skills - Modelling skills - Information Modelling
Facility Manager	Responsible for the logistic and planning use asset	- Technical skills - Information Modelling - Coordination (IPD)
Information Manager	Have an overview of the entire information requirements	- Coordination - Communication - Strategy
BIM Manager	Develop a proper BIM Execution Plan, establish protocols, coordinate and keep updated the different teams and take care of the federated model. Assuring the information produced by the teams are compliant with the BEP and the EIR.	- Scope of work - Strategy - Organisation and Planning (set milestones and deliverables) - Coordination representing the teams' interdisciplinary models - Open Collaboration (IPD) - Standardisation - Management and quality control of the information model meets the requirements - Create standards and protocols - Create process and workflows - Training strategy - Research
BIM Coordinator	Manage and control the single discipline model reviewing and approving the information produced.	- Organisation and Planning (set milestones and deliverables inside the team) - Standardisation - Management and quality control of the information model - Create process and workflows for the disciplinary team
BIM Modeler	Model creation and ownership, output the related documentation production. They are ensuring the coordination between all the elements of the BIM model.	- Technical skills - Software skills - Modelling skills - Information Modelling
BIM Consultant	Responsible for the BIM adoption, of protocols, Standards and implementation	- Support the company and the teams in the BIM use and adoption - Verification of the project team's competency level - Teams training - Implement strategies, protocols and workflow - Knowledge exchange concerning tools, software and knowledge of BIM for the company - Creating best-practice documents - Teaching new working methods - Research

The second developed matrix was created to evaluate a team member on the specific competencies required for the project. Here, traditional and BIM roles and mixed, and their overlap is evident. In the rows we can find the team members' name, traditional role and – whether applicable –assigned BIM role. It is an interactive matrix as every time a role is filled in by means of a drop-down menu, the last two columns are automatically filled with the role competencies description, so as to help the assessment when evaluating. Competencies are going to be rated from 0 to 5, divided into three main groups: Production, Management and Strategic. The rate average includes 0 because, since different roles require different competencies, it is not necessary to have all of them. For example, it is not required that the client has modelling competencies (Production) or that the BIM Modeller architect has the expertise needed to produce an EIR (Management). As regards the role of the Client/Owner, the BIM Manager will be the one to assess their competencies and drive them towards implementing them. The BIM Manager role assessment could be compiled by the Consultant or even by the BIM Manager itself via self-evaluation – the self-evaluation is accepted due to the fact that the BIM manager is deemed to act in compliance of the principles of best practice and on the Client/Owner's behalf (see Table 8).

As regards the final evaluation, it was decided to opt for an assessment made by a person instead of a mathematical formula, to take into account each project's uniqueness and any possible difference in the BIM's maturity level. The evaluation criteria will depend by the project needs and its requirements. This will have, therefore, to be evaluated and consequently approved by either the BIM Manager or the Project Manager.

The matrix may be used to evaluate the members of a teams before a project starts or as an annual competencies assessment for internal purposed, thus keeping track of the personnel's progress. It could also be used at the end of the training period, as an evaluation method of the employees.

Table 8 – Project's team members maturity level assessment

Surname	Traditional Role	BIM Role	Weight rate for the project team's members competencies assessment 0-5																		Traditional Role's Competencies	BIM Role's Competencies
			Production			Management					Strategic											
			Modelling	Drawing production	Documentation production	EIR	BEP	Model Coordination	Model Quality Control	Information Content Creation and Contol	Scope of Work	Strategy	Organisation and Planning	Open Collaboration attitude	Standardisation	Process and workflow development	Research	Implementation	Training	Certifications		
1	Client/Owner		0	0	1	4	0	0	0	0	3	3	2	4	1	0	0	0	0		Write a proper EIR	#N/D
2	Architect	BIM Coordinator	1	1	1	0	2	2	3	4	3	2	3	2	1	3	0	0	0		Main designer - miss client's requirements	Manage and control the single discipline model reviewing and approving the information produced.
3	Architect	BIM Modeller	4	3	3	0	0	0	2	2	0	0	0	2	0	0	0	0	0		Main designer - miss client's requirements	Model creation and ownership, output the related documentation production. Ensuring all elements of the Information Model are fully coordinated with each other.
4	Engineer	BIM Coordinator	2	2	2	0	2	4	4	4	3	1	3	3	1	2	0	0	1		Explore different solutions according to architectural design	Manage and control the single discipline model reviewing and approving the information produced.
5	Engineer	BIM Modeller	4	4	3	0	0	0	2	3	0	0	0	0	0	0	0	0	0		Explore different solutions according to architectural design	Model creation and ownership, output the related documentation production. Ensuring all elements of the Information Model are fully coordinated with each other.
6	Project Manager	BIM Manager	1	1	1	0	4	4	4	3	3	4	3	3	2	2	1	1	1		Make sure the entire team will achieve client's requests according to specifications	Develop a proper BIM Execution Plan, establish protocols, coordinate and keep updated the different teams and take care of the federated model. Assuring the information produced by the teams are compliant with the BEP and the EIR.
7	Contractor		1	1	2	0	0	0	2	3	3	3	4	3	2	0	0	0	0		Identify design issue before the construction phase starts	#N/D
9	Quantity Surveyor	BIM Coordinator	3	3	3	0	0	3	3	2	0	0	0	0	2	0	0	0			Manage and control project costs and contractual administration	Manage and control the single discipline model reviewing and approving the information produced.
10	Facility Manager	BIM Coordinator	1	1	1	0	0	2	2	3	0	0	0	3	0	0	0	0	0		Responsible of the logistic and planning use asset	Manage and control the single discipline model reviewing and approving the information produced.
11	Architect	BIM Consultant	0	0	0	0	3	4	4	4	4	4	4	3	3	4	3	4	4		Main designer - miss client's requirements	Responsible of the BIM adoption, of protocols, standards and implementation

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3. DEVELOPMENT OF AN INFORMATION WORKFLOW FOR THE DESIGN STAGE

The philosophy behind BIM is to better manage information. But what is the definition of *information*? The Cambridge Dictionary (2020) defines it as '*facts or details about a person, company, product, etc.*'. The IM is the process in which collected information is managed within a workflow inside a cloud service. In this Cloud Platform, the information is verified and used to generate new information, producing documents that will be shared in data format with other software and then processed, stored and finally retrieved (Figure 6).

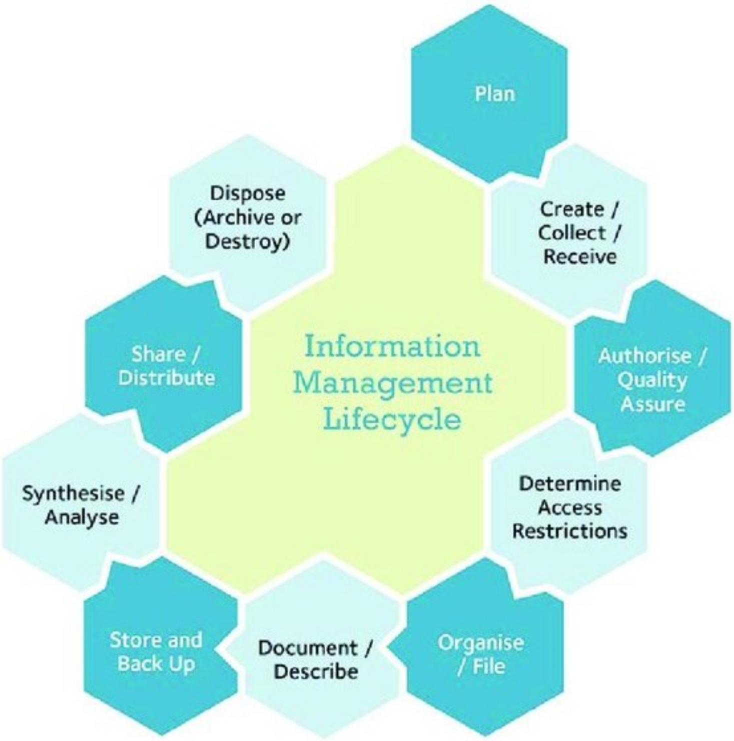
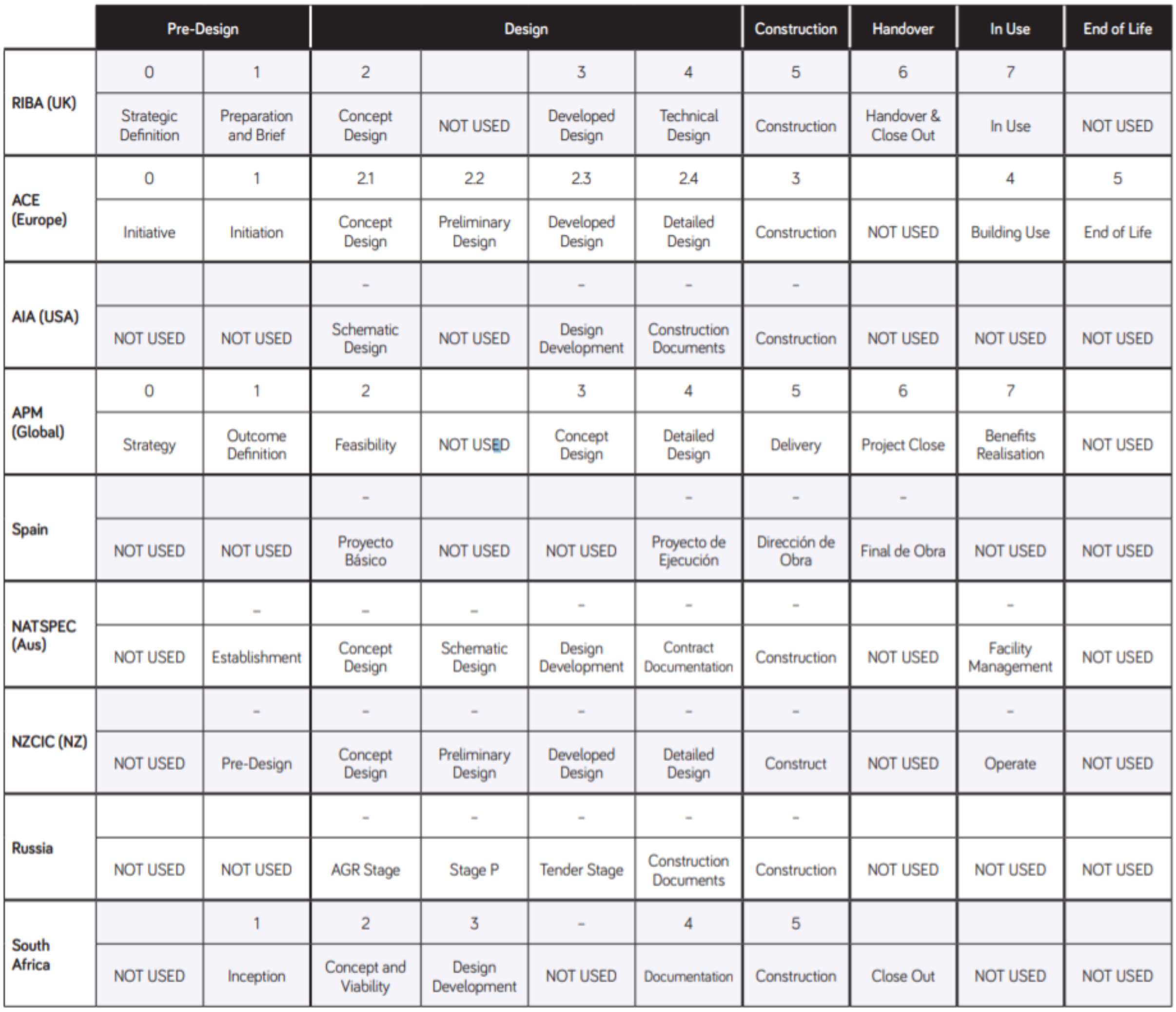


Figure 6 – Information Management lifecycle (Brown et al., 2016)

Before the advent of BIM, 2D drawings and 3D model information (wall layers, certifications, product specifications and supplier among others) were handled separately in the AECO industry (Sacks et al., 2018). One of the innovations introduced by BIM was the capability to carry, store and manage information throughout the project's lifecycle, from the Design Stage to the Operational and Maintenance phases. Information indeed could be created or acquired by the designer, then organised and stored within the model or the Common Data Environment (CDE), and finally distributed to other project stakeholders in a collaborative environment and used to generate additional information. As the capability to manage information is crucial in BIM implementation, this work aims at developing a workflow for building Design which uses the best practices found in articles, BIM guides, and Standards to promote a process that is more fluid and fast.

The Information Management also regulates processes across the project phases. Each country or organisation, as per Standards, developed their own plan of work, subdividing the Workflow and the procedures into different stages. The Royal Institute of British Architects (RIBA) collected and compared several work plans from other countries in order to compile the one for the UK (Table 9). So, to match the countries' project phases, these were grouped under six main stages: Pre-design, Design, Construction, Handover, In Use and End of Life.

Table 9 – Plan of work comparison (RIBA, 2020)



	Pre-Design		Design				Construction	Handover	In Use	End of Life
RIBA (UK)	0	1	2		3	4	5	6	7	
	Strategic Definition	Preparation and Brief	Concept Design	NOT USED	Developed Design	Technical Design	Construction	Handover & Close Out	In Use	NOT USED
ACE (Europe)	0	1	2.1	2.2	2.3	2.4	3		4	5
	Initiative	Initiation	Concept Design	Preliminary Design	Developed Design	Detailed Design	Construction	NOT USED	Building Use	End of Life
AIA (USA)			-		-	-	-			
	NOT USED	NOT USED	Schematic Design	NOT USED	Design Development	Construction Documents	Construction	NOT USED	NOT USED	NOT USED
APM (Global)	0	1	2		3	4	5	6	7	
	Strategy	Outcome Definition	Feasibility	NOT USED	Concept Design	Detailed Design	Delivery	Project Close	Benefits Realisation	NOT USED
Spain			-			-	-	-		
	NOT USED	NOT USED	Proyecto Básico	NOT USED	NOT USED	Proyecto de Ejecución	Dirección de Obra	Final de Obra	NOT USED	NOT USED
NATSPEC (Aus)		-	-	-	-	-	-		-	
	NOT USED	Establishment	Concept Design	Schematic Design	Design Development	Contract Documentation	Construction	NOT USED	Facility Management	NOT USED
NZCIC (NZ)		-	-	-	-	-	-		-	
	NOT USED	Pre-Design	Concept Design	Preliminary Design	Developed Design	Detailed Design	Construct	NOT USED	Operate	NOT USED
Russia			-	-	-	-	-			
	NOT USED	NOT USED	AGR Stage	Stage P	Tender Stage	Construction Documents	Construction	NOT USED	NOT USED	NOT USED
South Africa		1	2	3	-	4	5			
	NOT USED	Inception	Concept and Viability	Design Development	NOT USED	Documentation	Construction	Close Out	NOT USED	NOT USED

In this dissertation a new plan of work was created within the developed Workflow, focused on the Design Stage for BIM implementation. The Pre-design Stage was also taken into account as a strategic phase to determine the subsequent Design Stage. The Pre-Design Stage is coincident with the stages that go from the establishment of the contract to the constitution of the team. The Design Stage, instead, is that part of the project that goes from the Concept Design – where the ideas and the collected requirements are presented graphically – to the 'Modelling and Coordination' and 'Design for Construction' stages. The latter is the last stage of the Design before passing to Construction, Operation and Maintenance.

3.1. Development of the Workflow for the Design Stage

In order to achieve the best results from a process and to effectively manage information, establishing a workflow is a critical issue. The development of the following workflow is based on research and literature review and it was born to accomplish the needs for an organised flow of information from the company partner of this dissertation work: *BIMMS – BIM Management Solutions*. This conceptual map of the process aims to be useful in achieving an advanced level of collaboration and for clarifying the responsibilities and tasks of the stakeholders. In the document, actors involved in the project will be able to visualise the entire process, thus developing an improved consciousness regarding open collaboration. This workflow aims at making evident and clear how and when each actor is involved in the process, trying to avoid single phases compartmentation. The developed document will take into account only the Design Stage, making reference to Fontana's dissertation (2020) work for the Construction and Operational stages. The workflow is prepared according to IPD methodology, the product of a collaboration among the stakeholders since the very early stage of the project. It is also based on the use of a cloud platform for Common Data Environment, a virtual space in which deliverables such as documents and models are contained.

The workflow is presented in its last version, improved and endorsed after validation by BIMMS.

3.2. Workflow Structure

The Design Stage is divided into three main processes: Strategic Definition, Preparation and Brief and Design. The latter is again divided into other six sub-stages: Concept Design, Spatial Coordination, Modelling and Coordination, Automatic Licensing, Detail, Design for Construction. These stages and sub-stages are listed in the columns. The rows, instead, contain three entries: Stakeholders, Activities, and Deliverables. A colour scheme permits to immediately understand and find each role in the process; each discipline has a colour assigned and a gradient is applied to all the related tasks, so as to better understand the workflow and the deliverables that each actor has to produce.

The stakeholders row was ideally divided into two different levels of involvement: one for the information management – BIM Manager and BIM Coordinator, at an upper level – and one for the operational roles – such as architects, engineers et al. Stakeholders may act alone or in a working group; if this is the case, the ones involved in it are grouped inside a dotted square. From each actor, a continuous arrow conduces to the expected deliverable. The arrow crosses the action row, passing through the box with the action description.

The activities row begins with a circle, representing the starting point of a new project, and then moves to the first action contained inside a red box. Red was chosen to represent an action because it is easily discernible and is generally associated to the idea of highlighting something of importance. Large arrows help follow the action flows, crossing stages and sub-stages and leading to the end of the process. The large arrow was selected, again, to emphasise the main action of the process. In this row it is possible to find the turbot sign, which represents a gateway used for the validation action: if the deliverable is approved, the process may continue; otherwise, it has to go back to the beginning to be corrected or modified.

The following row is dedicated to the Common Data Environment. For the sake of best practice, only one platform was used in this workflow as a unique source of information. Inside the virtual space of the CDE, the deliverables are stored. For a clear comprehension of the deliverable, the author decided to split this last row into a 'documents' and a 'models' row. Files are considered documents and the association between them is expressed with a dotted, white arrow. Milestones are considered as documents, since they are established and derived from the BEP.

Finally, the last row is dedicated to the project models. Here one could see how the model evolves during the project and which are the processes to assemble it. As already mentioned, each discipline model follows the colour scheme and the relationship between models are displayed as a black, dotted arrow. In this row, the library object stored inside the CDE is also contained and treated as one of them. The workflow process finishes pointing with the process arrow to the Construction and Operational phases, which will not be discussed in this dissertation work. For a better comprehension, a simplified schema of the workflow structure is presented in Figure 7. In the following subchapters each one of the workflow sections will be explained in detail accompanied by its related image.

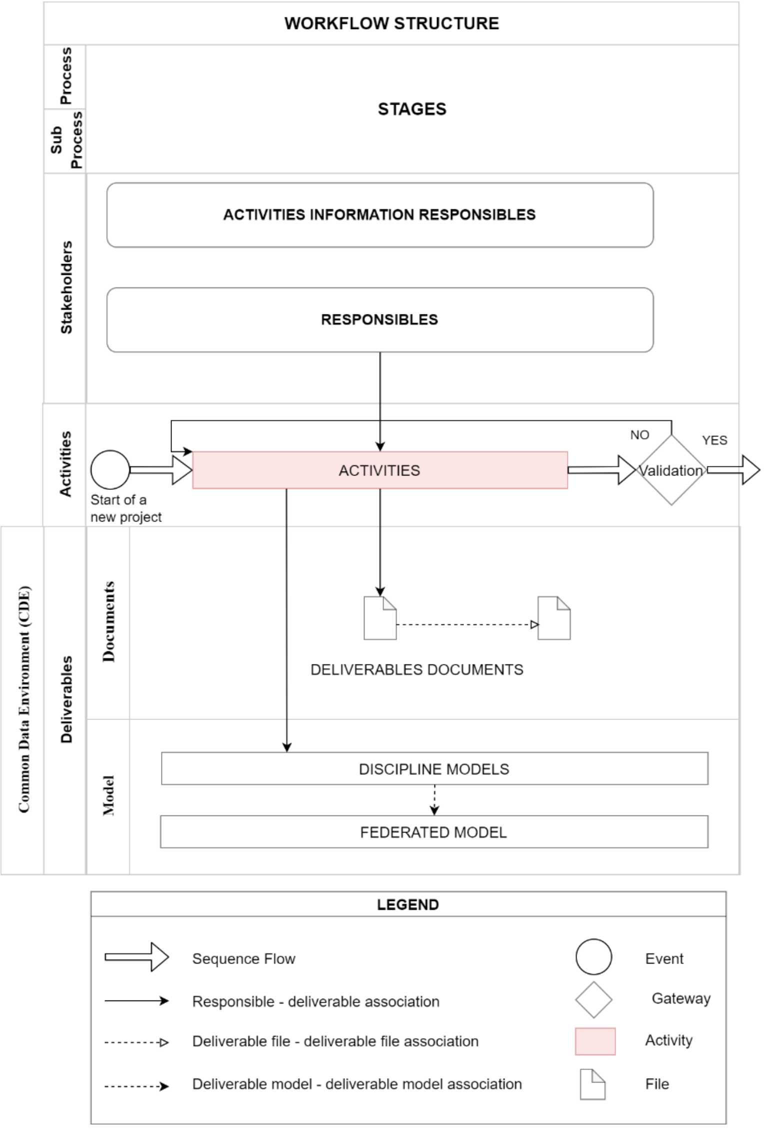


Figure 7 – Workflow structure

3.3. Strategic Definition

Every time a new project begins, the Client/Owner has to appoint a BIM Manager (the lead Architect, the Main Contractor or others) who will act on his behalf during the entire project's lifecycle. The BIM Manager will lead and help him to manage the information process (see Figure 8).

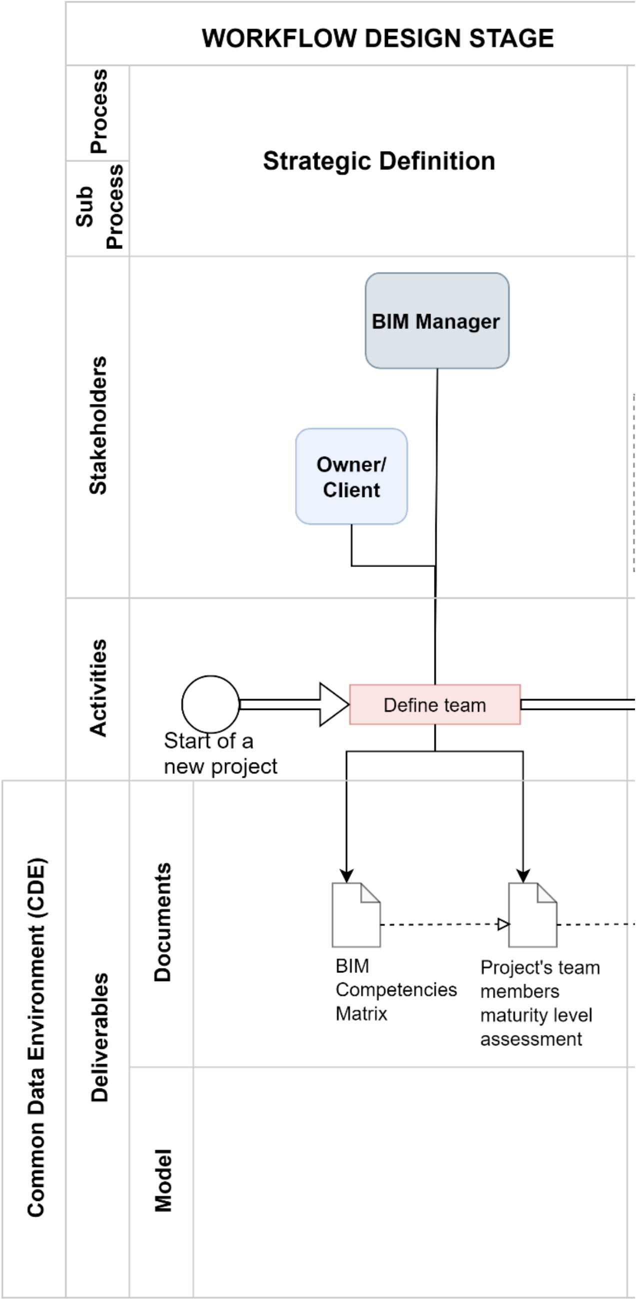


Figure 8 – Strategic Definition

During this stage, the two stakeholders assess the project's team and the members' capabilities according to their responsibilities. To accomplish this task, they will use the developed competencies matrix and the project's team members maturity level assessment matrix (2.2). Once the team is defined and assessed, it is possible to proceed with the second stage using the developed matrixes as a basis for the following documents.

3.4. Preparation and Brief

According to IPD procedures, this is the phase when a working group composed by the main stakeholders and led by the BIM Manager is settled. The owner sets the strategic definition on an operational level in the Organisational Information Requirements (OIR), creating a framework for the project and the Project Information Requirements (PIR). Then, on the OIR basis and with the help of the Facility Manager, they will set out the Asset Information Requirements (AIR) for the building asset requirements. Once these documents are ready, the working group – which shall be composed by each task team's team leader –sets a series of meetings to raise and establish all the requirements needed for each side. Nowadays, in projects regarding existing buildings it becomes more common the use of a laser scanning and Cloud points to reproduce the Asset Information Model (AIM). In those cases the Surveyor will bring his contribution inside the working group (Figure 9).

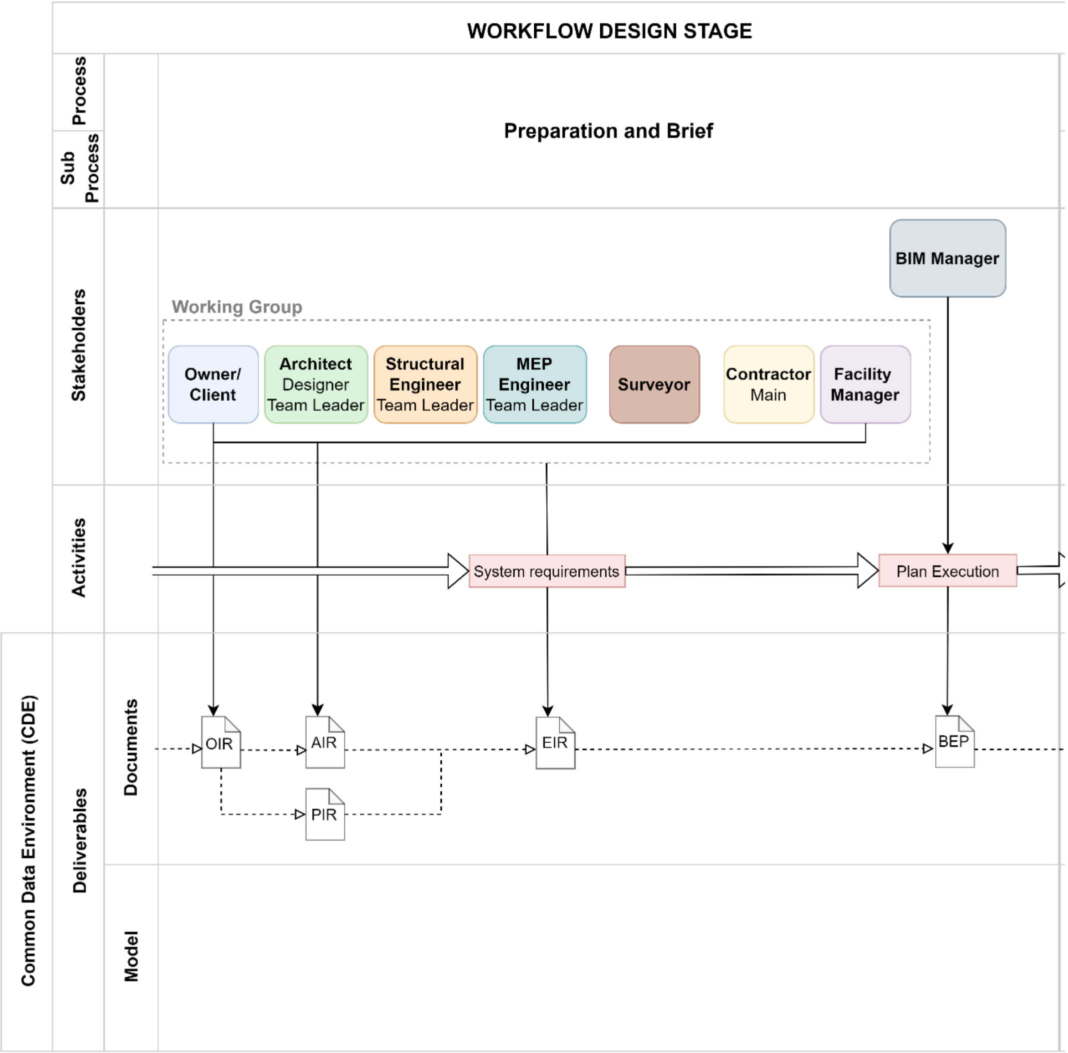


Figure 9 – Preparation and Brief

The BIM Manager has the responsibility to coordinate these working group meetings and write down the EIR and the BEP on these basis, summarizing and organising the teams' requirements. During the BEP collating and adding, they also set protocols, coordination milestones, and procedures that have to be followed by all the teams (British Standards Institution, 2013).

3.5. Design

At this stage, work was divided into six sub-stages, so as to identify which are the stakeholders involved in the process, if they work alone or in a working group – showing the relationships with the others – and which are the required deliverables for each sub-stage.

3.5.1. Concept Design

In this stage, the Client/Owner and the lead Architect lay down the project requirements. The specifications concern the design according to the building facility purpose and specifications. During this period, several meetings take place between the two, before the building design takes its shape (Figure 10).

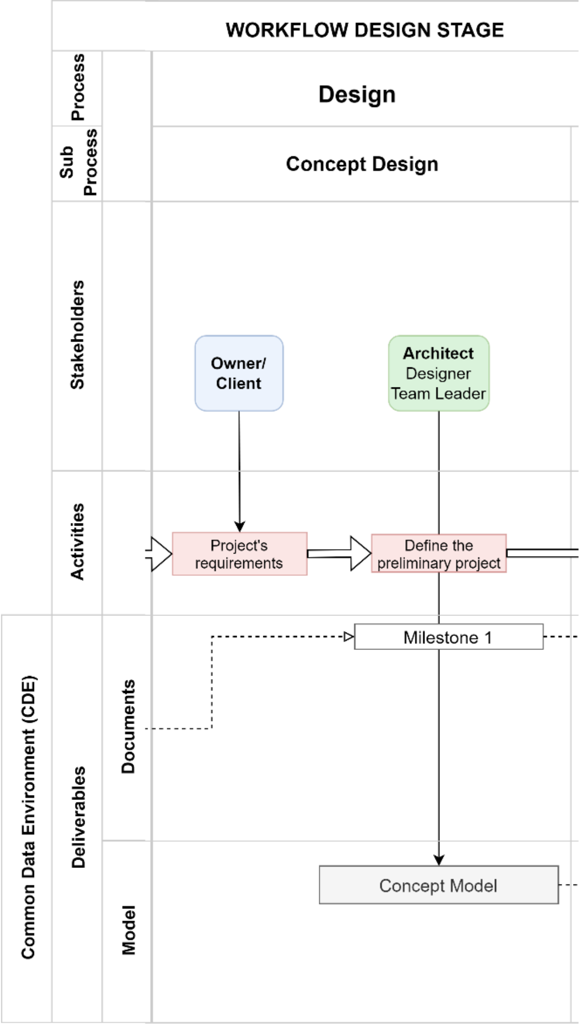


Figure 10 – Concept Design

According to the BEP, during the Concept Design Stage, the first Milestone occurs. For this meeting, the lead Architect must present the first conceptual drawings of the building and deliver the final Concept model. This model, generally, is not filled in with information and it is made with software such as Sketchup or Rhino using masses, meshes, surfaces and NURBS. This model will be the basis on which to start the Information model with one of the BIM available tools for the design.

3.5.2. Spatial Coordination

On the Concept model base, a new working group is settled between the lead Architect, the Structural Engineer, the MEP engineer, and the Facility Manager, coordinated and supervised by the BIM Manager. This group focuses on Spatial Coordination, deciding the requirements needed for the building's structure, the space required for the Mechanical Electrical and Plumbing features according to the building dimensions and the users who will populate it after the project handover. The Facility Manager is also involved in the decisional phase to define the space needed for the logistic evaluating the post-occupancy phase as well as the operational phase (Figure 11).

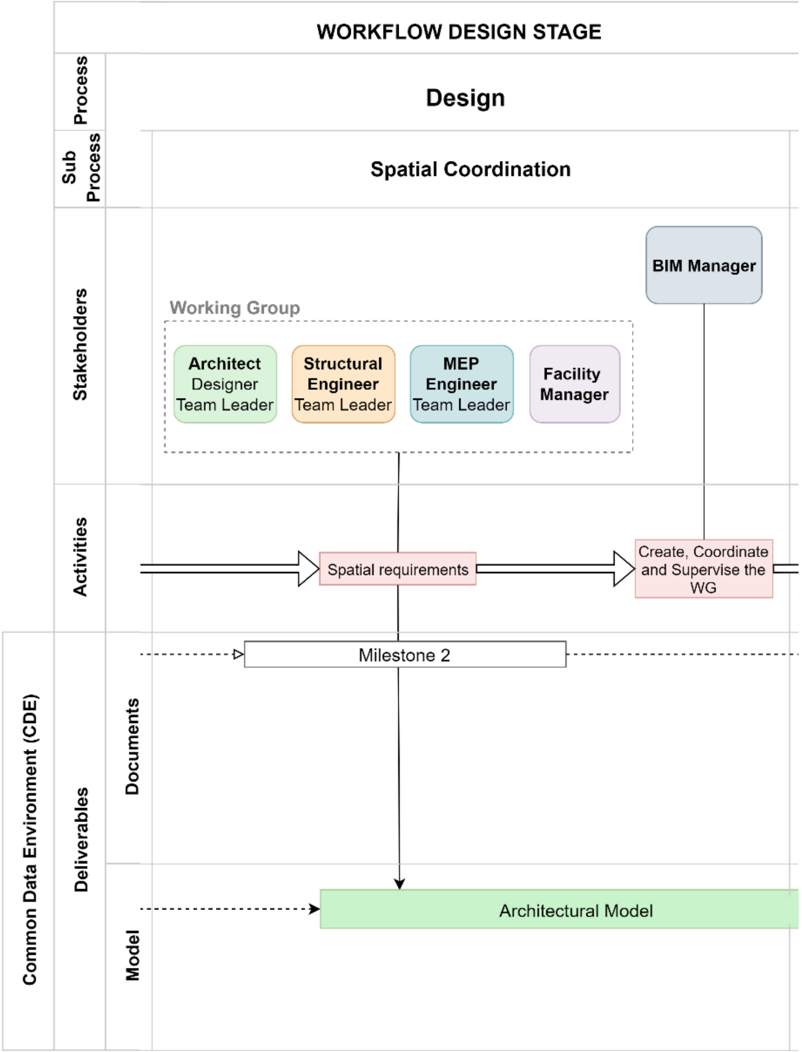


Figure 11 – Spatial Coordination

Once these requirements are identified, the lead Architect collects them and starts creating the Architectural model. This model is built on Concept one, but is developed using BIM software and begins to be populated by information – such as the dimensions of the walls, the redefinition of doors, the position of the windows, and adequate spaces for MEP and facilities. In this stage, it is imperative to establish shared coordinates for the model to be used later on for coordinating with the other teams. This stage is the second Milestone, where the lead Architect has to deliver the last version of the Architectural model.

3.5.3. Modelling and Coordination

The Architectural model with its shared coordination constitutes the foundation on which the other task teams may develop more models. A BIM Coordinator organises each discipline team and is always in contact with others BIM Coordinators to check and share information. This high-level of information management group is led by the BIM Manager, who has the duty of supervising the information flow and the teams' coordination. Each team may receive certified objects to populate their model from the chosen Suppliers. If the Supplier is not already selected, the BIM Manager should be the one in charge to establish the geometrical and information detail of the object. Once inserted in the model, these objects must be stored inside the shared Objects' Library in the CDE for mutual use (Figure 12).

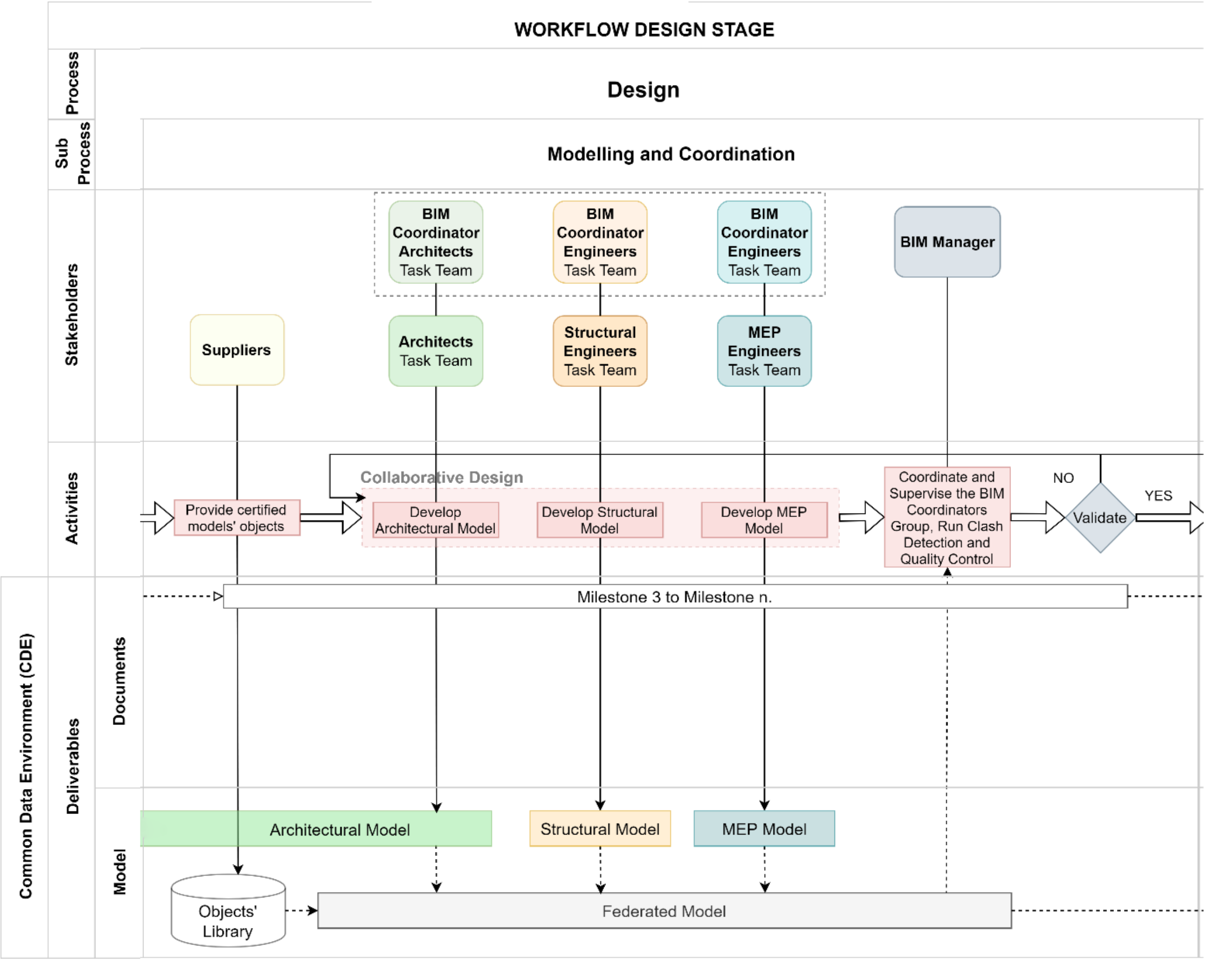


Figure 12 – Modelling and Coordination

During this stage, several Milestones occur according to the BEP plan. Every day, each task team uploads the last version of the model – or works simultaneously – inside the CDE's WIP folder, both in the native format and in IFC (6.1.1). At each Milestone deadline and after the BIM Manager’s approval, the BIM Coordinator uploads the last version of the task's model in the IFC format. Collecting all the discipline's models, the BIM manager then assembles the Federated model, runs the Clash Detection and Quality Control (5.2). After this step, the BIM manager sends a report to the BIM Coordinators, reporting all the issues that need to be corrected. After the last Milestone, if the final check is positive, the BIM Manager prepares the model for the following stage.

3.5.4. Automatic Licencing

After the Federated model is approved by the BIM Manager, it is submitted to the authorities for validation. Today the check is made manually by the municipality's employees; in the future, it will probably be made by an automated software. In any case, if the submission is approved, the workflow can continue his path; otherwise, a report with mark-ups will be sand back for corrections (Figure 13).

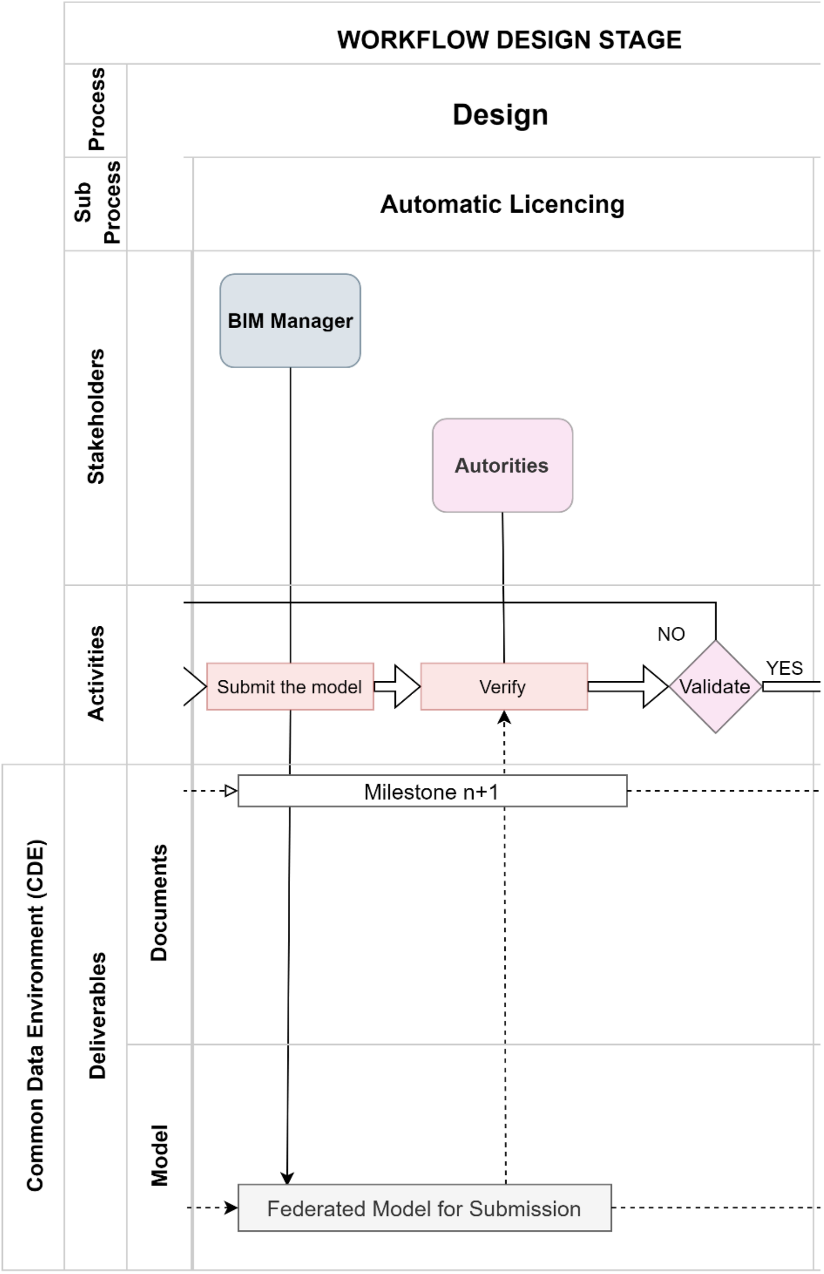


Figure 13 – Automatic Licencing

3.5.5. Detail

Once the authorities approve the project, a new stage begins. Now each discipline team has to produce and extract from their model details and documentation in several formats according to the agreed BEP Milestone (Figure 14).

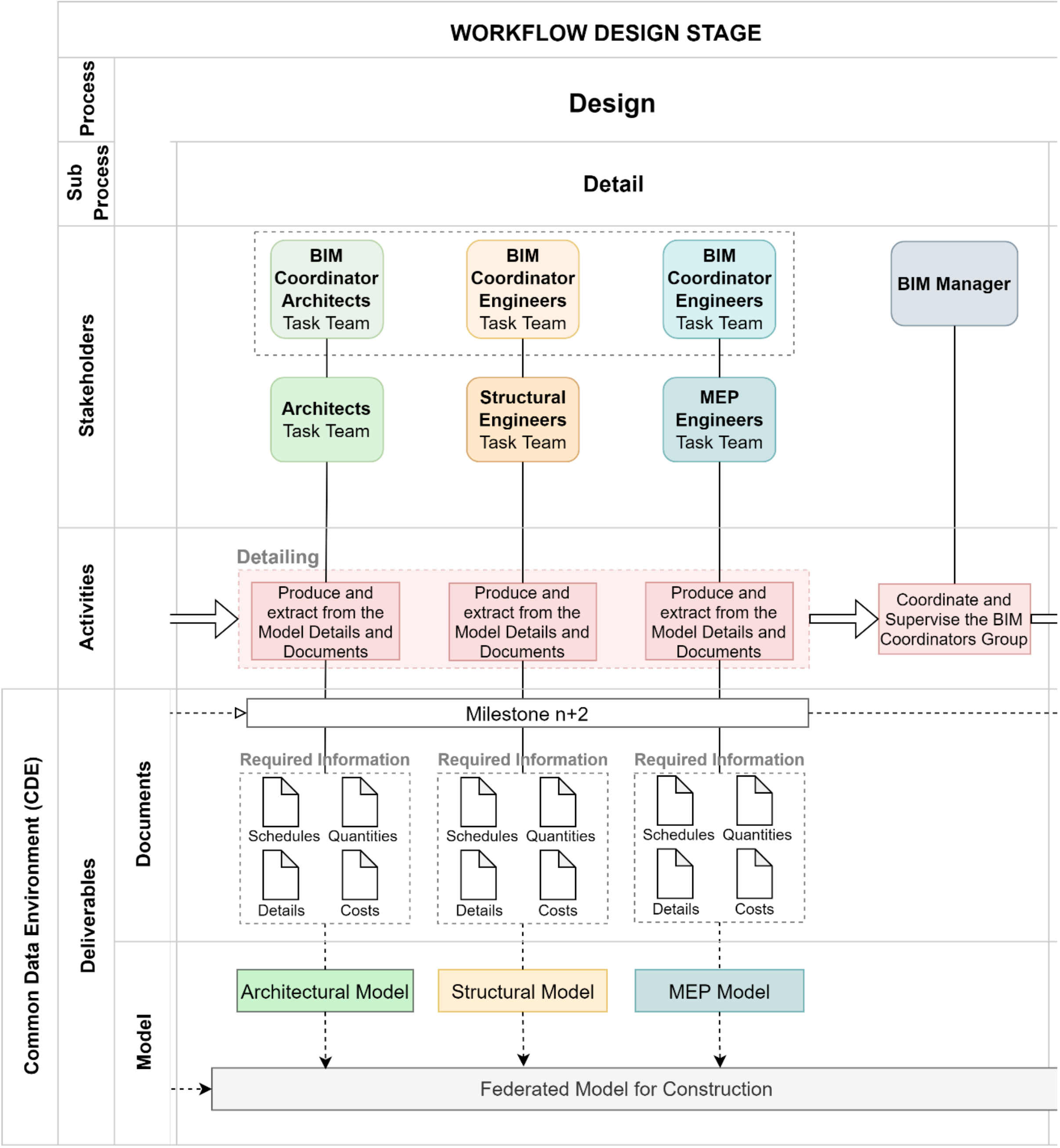


Figure 14 – Detail

The exchange format may be pdf, excel, COBie or other for documents and IFC for models to be collected in the Federated model for Construction. Those deliverables are meant to be provided for the Contractor to produce objects and furniture for the construction site. As per the previous stages, each team is coordinated by the BIM Coordinator and supervised by the BIM Manager.

3.5.6. Design for Construction

Once the last version of the models and the details are ready in the federated model, they are passed down to the Contractor, the Sub-contractor, and the Facility Manager. From the Construction model, the stakeholders are able to extract the information they need to produce objects for the construction site, according to the correspondent Milestone (Figure 15).

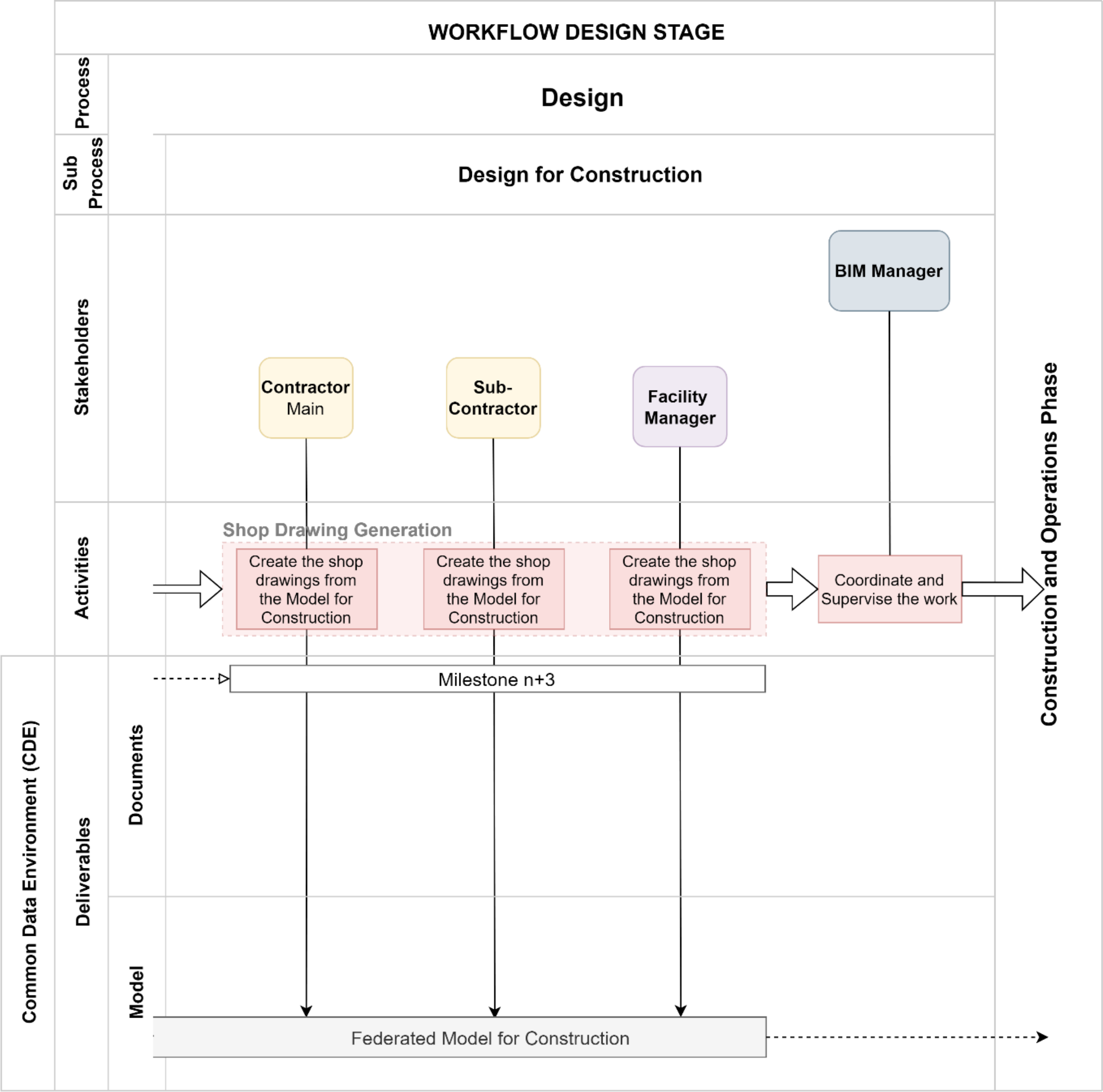


Figure 15 – Design for Construction

In this stage, Contractors need to modify the original model in order to create the shop drawings and to adapt the objects to be produced. It could also happen that the Contractor might prefer to create a brand new model, instead of using the delivered one, with a different template. Once the shop drawings and the models are ready, the information then passes to the next stage of the workflow, to be used in the Construction and Operational phases.

3.6. Global Workflow

In the following image (Figure 16), it is possible to analyse the complete workflow and to assess how the information flow goes from the start of the new project to the Construction and Operation stages. Throughout this process, information improves and gets completed. The model, started as an agglomerate of masses, is now full of complex objects and carries information and documents in detail. All stakeholders participated in this process, having created an open collaboration and improved the process flow. This workflow will be used by BIMMS in future projects implementation.

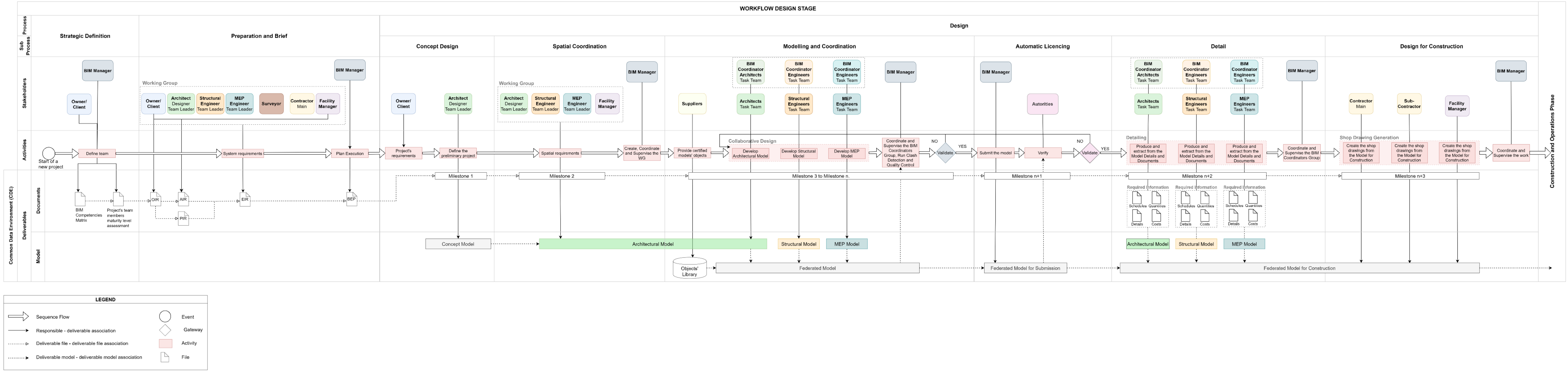


Figure 16 – Developed Workflow

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4. INFORMATION REQUIREMENTS

Information requirements stand at the core of the information management. BIM is not just about a set of software or 3D modelling; it is a tool developed for delivering the right information to the right destination at the right time, taking into consideration structured and unstructured information. To understand which type of information is needed, it is crucial to understand the purpose for which the information is required. Information requirements reflect the receiver's needs: if they are not sufficiently precise, this may leave the providers in a situation where they have to make assumptions, possibly generating waste data. It is also essential to establish how the information has to be delivered, as to avoid both time-wasting and information-lacking. All parties – not just the client – should precisely define the information they require to carry out their actions (Walters, 2020). This can be problematic for unexperienced employers, who may have a shallow understanding of the building and no knowledge at all of BIM. In BIM adoption, indeed, it is fundamental to receive the Information Requirements from the client. An unexperienced Client/Owner may appoint an architect or a contractor to help him define the project. As a result, the adoption –or rejection – of BIM is based on the advice they receive and its implementation. It could be useful, therefore, for unexperienced employers to hire an external BIM Consultant, who may help them since the very start of the project, determining how BIM should be used. The advice of an expert becomes essential especially in the early stages, when it can help the Employer lay down the Information Requirements needed by the rest of the team to make critical decisions.

4.1. Literature Review

Each country defines and controls the Information Management via some established Standards. For the purpose of this work, four BIM Standards were considered: American NBIMS, British PAS, International ISO and Italian UNI. It is difficult to find articles that delve in the EIR and provide a proper and precise definition. Many of them are generic on ISO Standards and PAS Standards. The ISO standard structure for the generation of an EIR and a BEP derives from the PAS Standard, but, while maintaining the same acronym 'EIR', its meaning changes into 'Exchange Information Requirements'. To clarify, it is essential to examine the two systems, and compare each other to the American and the Italian systems as well.

4.1.1. The American System

The US system bases BIM processes on three different tools: the National BIM Guide for Owners, the BIM Project Execution Plan Guide (V2.2) (2017), and the USACE BIM contract requirements.

The National BIM Guide for Owners (NGBO), developed by the National Institute of Building Science, helps BIM owners establishing and developing their requirements for the project and how the information should be delivered. These requirements are written in the **Owner's Project Requirements** (OPR) and are described by the National BIM Standard – United States (NBIMS-US) Version 3. OPRs are the basis on which the building's design team works, completing them while they are defining the building's asset. In the OPR, it is the owner – or the BIM Manager on his behalf – who needs to identify the BIM goals and the requirements. They also have to specify at least the minimum five Essential BIM Uses (Existing Conditions, Design Review, Design Authoring, 3D Coordination, and Record Modelling) developed by the Pennsylvania State University (see Figure 17). After this, the Project BIM team identifies the roles and responsibilities of the stakeholders and develops a BIM Project Execution Plan (BPxP). The OPRs are then inserted inside the BPxP, so as to function as the basis for its creation.

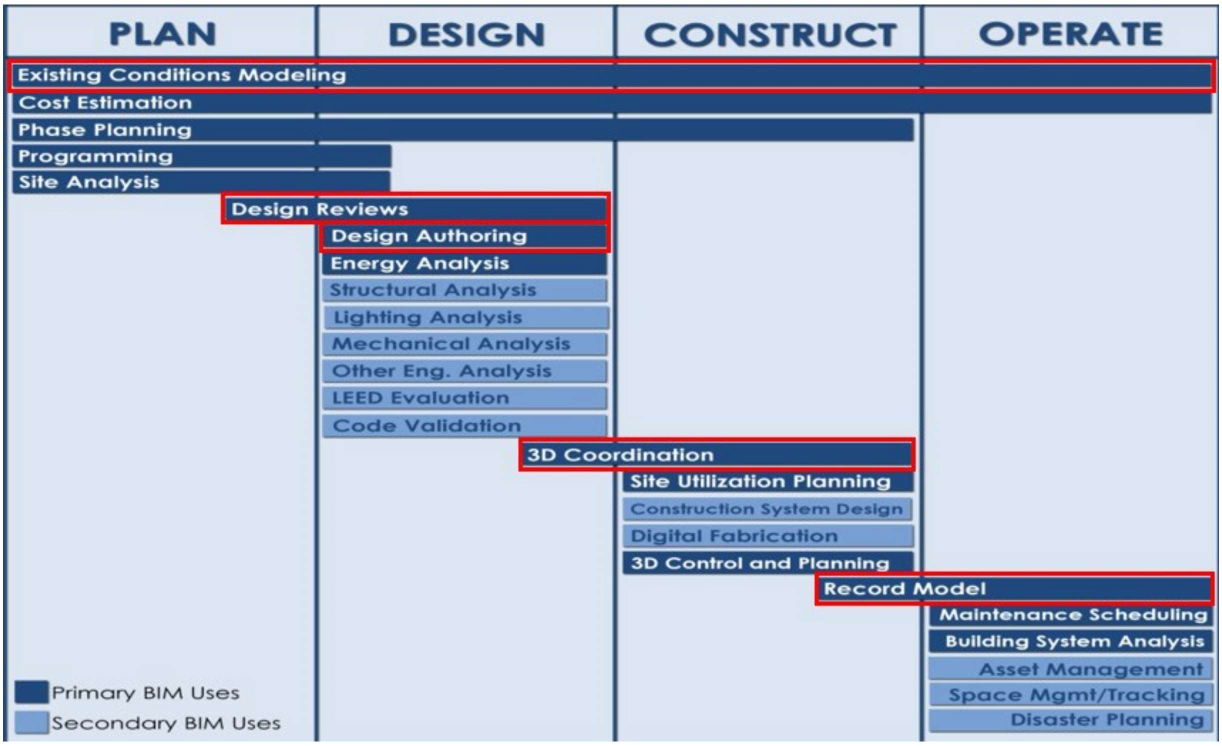


Figure 17 – BIM Uses - adapted from (Messner, Anumba, et al., 2019)

4.1.2. British System Standard (BS-PAS)

The BS 1192, by British Standard Institution (BSI), that concerns production, distribution and quality control of the information, including the construction information, published its first edition in 1990 and the second one in 1998. The third edition was released in 2007 with the title: 'Collaborative production of architectural, engineering and construction information. Code of practice,' referencing, along with 2D drawings, also 3D model as an information system applied to project phases. The last revision was carried out in 2015 and in 2018 it was announced that ISO 19650 would replace BS 1192 namely PAS 1192-2.

BS PAS 1192-2:2013

It was commissioned by the Construction Industry Council (CIC) as a response to the UK Government Construction Strategy, which required 'fully collaborative 3D BIM' for all projects with electronic data of asset information and documentation as a minimum by 2016' (BIM Level 2 as in Figure 3). It is the Specification for information management specifically focused on project delivery, and it is built on the BS 1192:2007 (and now replaced by BE EN ISO 19650) code of practice for the collaborative production of architectural, engineering and construction information. It begins with a statement of need and it is applied among all the information delivery cycle up to the as-constructed Asset Information Model (AIM). It specifies the requirements for five stages of information delivery divided into three main categories (now replaced by BS EN ISO 19650):

Procurement:

- Employers Information Requirements (EIR);
- BIM Execution Plan (BEP);
- Project Implementation Plan (PIP);
- Supplier BIM assessment, Supplier information technology assessment, Supplier resource assessment and Supply chain capability summary forms.

Post contract:

- Post contract award BIM Execution Plan;
- Master Information Delivery Plan (MIDP);
- Task Information Delivery Plan (TIDP).

Production:

- Common Data Environment (CDE);
- File and layer naming conventions;
- Spatial coordination;
- Publication of Information;
- Design for bespoke manufacture;
- Using assemblies and library information;
- Levels of model definition;
- Levels of model detail and model Information;
- Classification.

BS PAS 1192-3:2014

The CIC commissioned it to the BIM Task Group as a response to the UK Government Construction Strategy for BIM adoption by 2016 and, same as PAS 1192-2:2013, it was built on the BS 1192:2007 and is the base of BS EN ISO 19650. It is a requirement for BIM Level 2 (Figure 3) for procured public projects. This Specification takes care of the operational phase of built assets trying to ensure consistency in the information exchange during the management and organisation of the project operational phase. It specifies how an Asset Information Model should be created and how the model should be used (Figure 18).

Organisational Information Requirements (OIR): describes the information needed to the asset management system at an organisational level.

Asset Information Requirements (AIR): defines the information required for the AIM. It could initially be in the form of a text, but it should then be converted into a digital deliverables plan. The AIR specifies which pieces of information and data have to be inserted and stored in the AIM. Indeed, it should be developed from the OIR and should be specified as part of a contract or as a direction for the in-house teams to carry out the activities management of the AIM. If the activities are related to major works, as specified in the PAS 1192-2, then the AIR informs the EIR. It may include ownership, contractual information, etc.

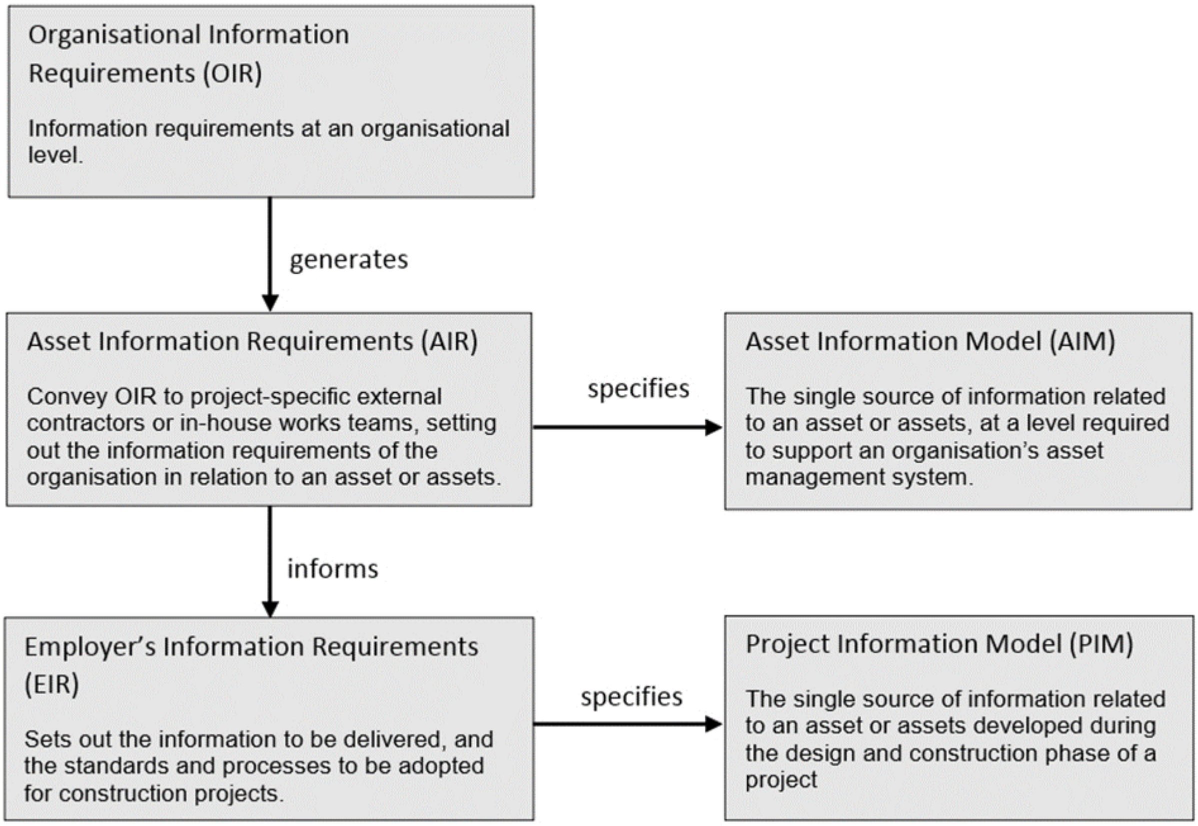


Figure 18 – Data transfer process structure according to BS PAS 1192-3:2014 (Design Buildings Wiki, 2020a)

Asset Information Model (AIM): is a model that provides all the required or related data and information about the operation of an asset. It can be created from a new information asset, from an existing one, or from a specifically generated Project Information Model. The stored data can be graphical or non-graphical, in the form of metadata or documents; the model may contain or refer to information about ownership, work done, surveys, and the operational phase. The AIM is managed within a single source of information – Common Data Environment (CDE) – which is generally organised in four main areas: Work in Progress, Shared, Published, and Archive (Figure 3). The AIM could be changed due to maintenance work, upgrades, repairs, et al.

Employer's Information Requirements (EIR): is developed by the employer to define the information they require for the development of the project (Figure 9). The Employer in the procurement documents appoints relevant extracts of the EIR to each Supplier (architects, engineers, contractors etc.), clearly describing the expected information deliverables as documents, structured information, or model files. He also defines when and how the information will be exchanged during the project lifecycle. The EIR complexity may depend on the Employer's BIM maturity experience: this is the reason why it is crucial for the unexperienced Employer to hire a BIM consultant, so as to be supported in the development of this essential deed. The UK government identifies NBS Toolkit as a tool to support the production of the EIR. An EIR, according to PAS 1192-2:2013, shall include:

- Planning of work and data segregation;
- Training requirements;

- Levels of detail;
- Coordination and clash detection;
- Requirements for bidders' proposals for the management of the coordination and collaboration process and for the CDE;
- Schedule of constraints set by the Employer for the model file, the exchange information, file format etc;
- Schedule for the software format and version NB PAS 1192-2 suggest that 'Public sector employers may not wish to or be able or specify software packages to be used by their suppliers, but may instead specify the formats of any outputs. Private-sector employers may choose to specify software packages and/or output formats'.

The EIR may also include:

- Standard methods defining how and when the information has to be exchanged and why it was created;
- Which role has to deliver that type of information;
- An information delivery plan;
- A COBie schema demand matrix, where data is defined about zones, spaces, floors and building components that should be delivered and when.

By using a BIM protocol – which defines the contractual definition of BIM limitation, liabilities and responsibilities – it is possible to establish the contractual status of the EIR. In Figure 19, we can clearly identify the relationships between the EIR and other contractual documents in a BIM process, according to the PAS Standard.

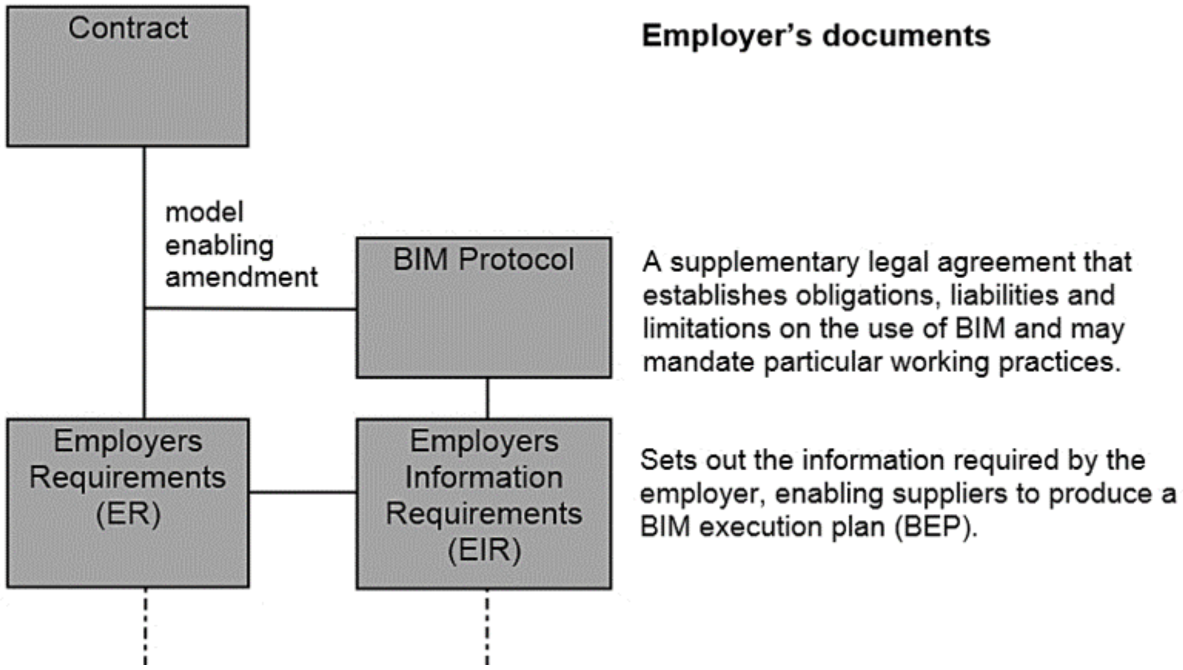


Figure 19 – Contractual documents' relationships according to BS PAS 1192-3:2014 (Design Buildings Wiki, 2020b)

Project Information Model (PIM): is a model progressively developed during the design and construction phases of the project (Figure 18). The federated model, composed by single task teams' models, contains structured and unstructured data and graphical and non-graphical data (BIM Dictionary, 2019); the EIR then sets out the requirements for its development (IFC format, COBIe files, PDFs, etc.). Once the construction phase is over, the PIM is transformed into the AIM for the operational phase. The PIM, as the AIM, is managed inside the CDE and the information is classified into the ordinary four main folders: Work in Progress, Shared, Published, and Archive (Figure 3).

4.1.3. International System Standard (ISO)

In 2017, the BSI proposed a new version of the ISO 19650 standard based on BS 1192. It was divided in two parts: ISO 19650-1, which introduced the practice to manage building information ('Organisation of information about construction works - Information management using building information modelling. Part 1: Concepts and principles') and ISO 19650-2, which provided requirements about the asset phase of the project ('Organisation of information about construction works - Information management using building information modelling. Part 2: Delivery phase of assets') A final version was released in 2019 with the title 'Organization and digitisation of information about buildings and civil engineering work, including building information modelling (BIM). Information management using building information modelling'. The Operational phase of asset is still under development.

The ISO Standard specifies IM requirements for processes management as in Figure 20, subdividing them into a Delivery phase – which uses the Project Information Model (PIM) – and an Operational phase – which instead uses the Asset Information Model (AIM). Between these phases, information is collected, processed, approved, used, and finally stored.

Figure 20 – Information Management process according to ISO Standard (ISO 19650-1, 2018)

ISO 19650, as mentioned before, is based on PAS Standard and replaced it in a few parts. This Standard classifies the characters of this information process as 'appointing party' (the one who establishes the requirements) and 'appointed party' (the one who receives the requirements to accomplish with the information); according to the ISO, during the process some appointed parties could also be appointing parties. It also categorises information into four main categories: purpose, content (content summary and content breakdown), form, and format. Furthermore, ISO 19560-1 clause 11.2 subdivides the levels of information in three further sub-divisions: geometrical information, alphanumerical information, and documentation. The information flow between the parties has to be continuous throughout the project, thus aiding the decision making and avoiding lack of information and waste of time. The ISO 19650 Information Requirements structure is similar to the PAS 1192-3, except for some minor differences (Figure 21).

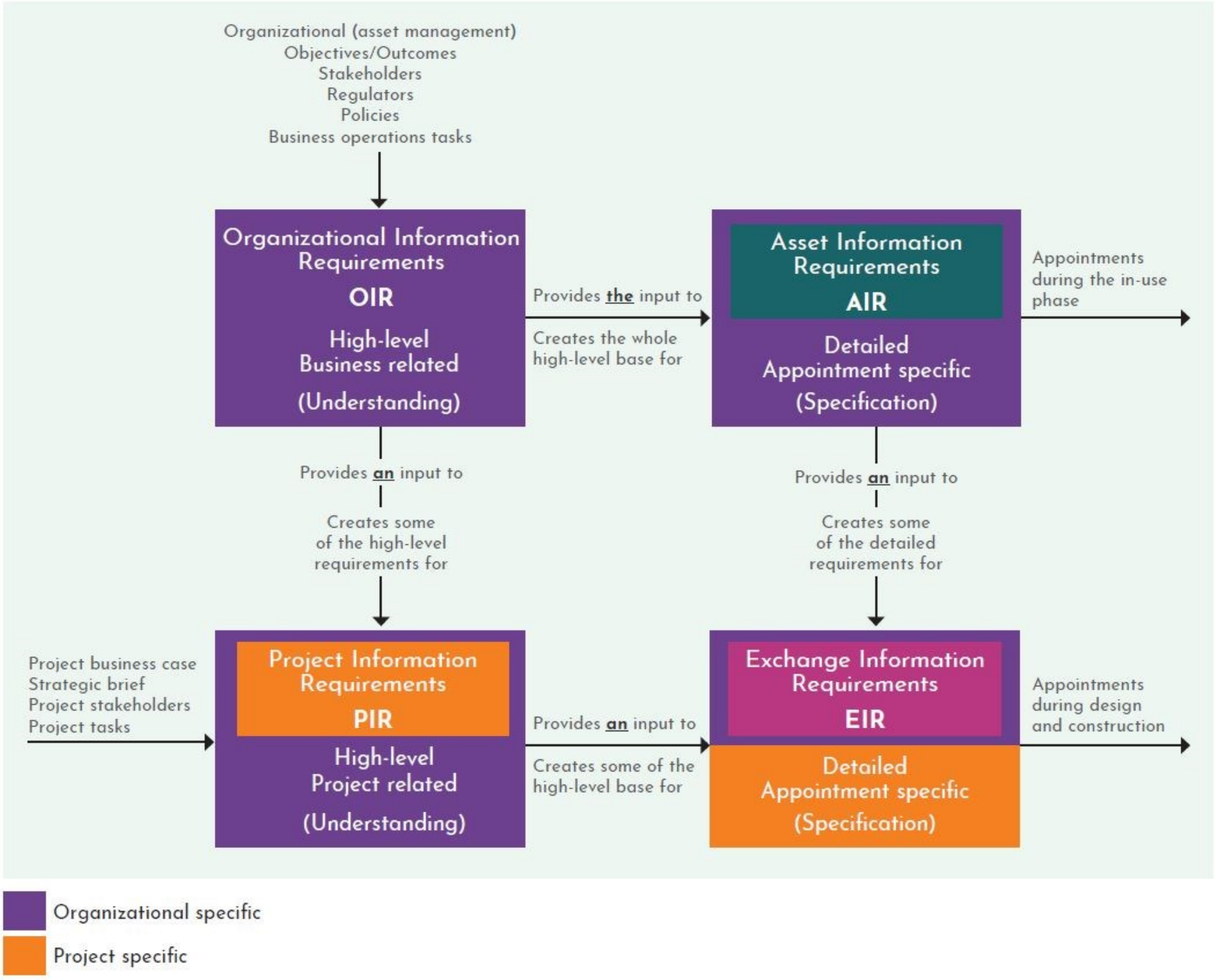


Figure 21 – Information transfer process structure according to ISO 19650-1 (Walters, 2020)

Organisational Information Requirements (OIR): as in PAS 1192-3, it helps create a structured framework for the information, so as to support the strategic business decisions among the project lifecycle defining requirements for each project delivery. ISO 19650-1 defines requirements as high-level information for high-level activities. It may be useful, for organisational purpose, to group these high-level activities into three categories: strategic, tactical and operational. These are the activities which create the OIR structure, but they are not sufficient on themselves to be considered OIR. To have appropriate OIRs, it is essential to specify the purpose for which those activities are created, which information is needed for each one of them, and to whom they are allocated.

Asset Information Requirements (AIR): as already specified in PAS 1192-3, they are a set of requirements (created before the appointment by the Client/Owner) to manage the physical in-use activities during the project lifecycle and to support the information delivery. An Asset of Information Model (AIM) is created from the AIR or from a Project Information Model once the building is constructed; ISO 19650-1 defines an asset as an entire building or just a part of it, a space or a piece of infrastructure, etc. The AIR may be changed during the project lifecycle as a result of an event that may cause a modification of the project, leading to an information updating and consequently to an incorporation in the AIM. AIR are specifically appointed, i.e. not established at the beginning of the project.

In this first part of the project information management lifecycle, PAS Standard and ISO Standard are the same, and the ISO 19650-1 (which as mentioned before was based on PAS) is today entirely replaced by the PAS. ISO divides the information needed in two categories: Project Information Requirements and Exchange Information Requirements. These sets of information have to be identified and established before the tender (RIBA may be used).

Project Information Requirements (PIR): are defined in ISO 19650-1 and ISO 19650-2 and derive from the OIR. They are comprised of some high-level information, needed by the appointing party in order to make their decision. Some PIR requirements could already be defined in the OIR; the additional ones have to be established before the appointments. Unlike to the AIR, there is only one set of PIR per project, and the appointing party does not have to produce a separate document. The definition of these requirements will become a Key Performance Indicators (KPI) for the most strategic decision of the plan of work described in BS 8536 for BIM Level 2 (Figure 3) and aligned with the RIBA work plan.

Exchange Information Requirements (EIR): are defined in ISO 19650-1 and ISO 19650-2 specifically in clause 5.2.1 – the appointing party's EIRs to be matched by the lead appointed party – and clause 5.4.3 – about which lead appointed party's EIRs have to be satisfied by the appointed parties. The EIR is composed by the appointing party (based on the OIR, AIR and PIR) and the lead appointed party (depending on the project plan of work) requirements. The appointing party's EIR specifies which information has to be delivered at each exchange, and it has to be clear enough to fulfil the project design or the operation phase activities. This part of EIR for the appointment process is the same as the information contained in the Employer's IR of PAS 1192-3. The combined EIR from the appointing and appointed parties during the project process are filtered to each team. ISO also states that, to have a proper EIR, the information should be organised and managed thusly:

- Purpose of Information: understand the use of information and subdivide it in a small system composed by input, process and output that will be the next input for the consequently low system;
- Structuring of Information: is the EIR part where it is specified which data for which primary purpose has to be exported and how to become an input for the secondary purpose.
- Definition of Information: define how the information needed has to broke down in its structured and unstructured information and which should be the level of definition of them.

4.1.4. The Italian System

In 2017 the Ente Italiano di Normazione published the UNI 11337 Standard, based on PAS 1192 and ISO 19650, which was divided into ten parts. UNI 1137:2017 describes the BIM process for the digital management of the building information processes. So far, only sections 1, 4, 5 and 6 were released:

- Section 1 introduces the origin and definition of the 'information'
- Section 4 addresses the quality of the information and LOD developing – a special LOD section for restoration
- Section 5 ("UNI 11337-5:2017," 2017) defines the roles of the stakeholders, requirements, and information management and process.
- Section 6 ("UNI/TR 11337-6:2017," 2017) gives the procedural guidelines and a schematic view about the Capitolato Informativo's contents (provides an example of an Information Requirements document and a BIM Execution Plan).

There it is yet no prevision on when the remaining articles will be published.

The **Capitolato Informativo** (CI) is the Italian version on the British Employer's Information Requirements and from it derives. Being created by the owner at the beginning of the building process, it is the fundamental document for tendering procedures, and its structure is similar to the UK EIR. It is divided into four sections: Premesse (General Information), Riferimenti Normativi (Standards) Sezione Tecnica (Technical Section) and Sezione Gestionale (Management Section) (Figure 22). The CI has contract value establishing the project objectives, the information exchange process and the collaboration system. This document is preparatory for the subsequent Offerta di Gestione Informativa and Piano di Gestione Informativa.

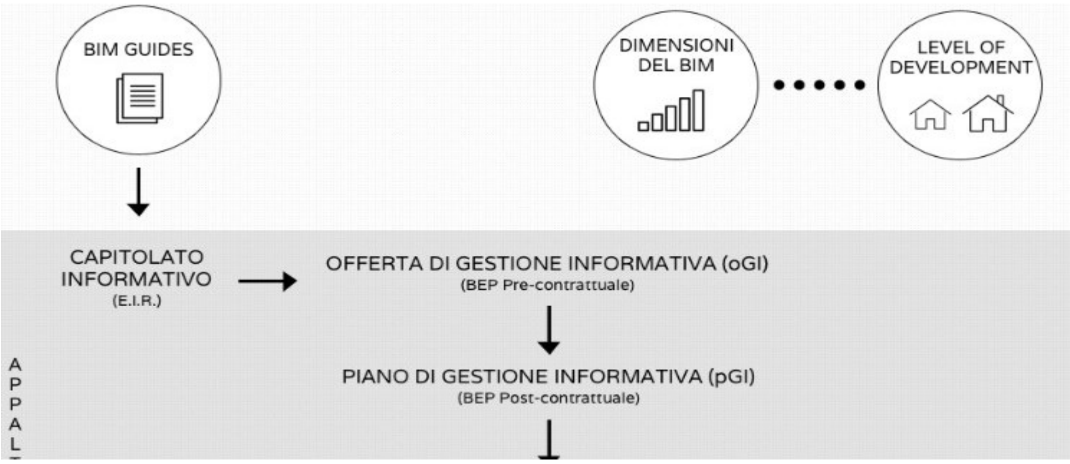


Figure 22 – BIM process according to the Italian system UNI Standard ("UNI/TR 11337-6:2017," 2017)

4.1.5. Comparison between the four systems

As stated above, it is apparent that the four systems identify the same three moments in the BIM process: (i) the Information Requirements settled by the Client/Owner, (ii) a tender process, and the (iii) award of the contract. The ISO and UNI Standards are based on the PAS model. Still, in the ISO Standard the

EIR (Exchange IR) takes a more pivotal role in containing the requirement of the client (i.e. the appointing party) and in adding the lead appointed information needs, hence producing a compound document that creates a framework for the resulting BEP. In the American system, on the other hand, the owner requirements are an integrated part of the entire BIM Project execution plan record and do not represent a separate document. What is interesting, as regards the American system, is that they developed a guide to help the owner fill the BPxP (OPR) from their own standpoint. In the table below (Table 10), see the document needed for the Information Requirements in the four national systems:

Table 10 – Listing Table for Information Requirements documents in various Systems - adapted from (Pavan, 2017)

Source	Document
UK (PAS)	EIR (Employer IR)
ISO	EIR (Exchange IR)
USA (NIBIMS)	BPxP (OPR)
ITA (UNI)	CI

4.2. Development of an Exchange Information Requirements template

The thorough analysis previously carried out on the four standard systems about the Information Requirements was used to support the development of an Exchange Information Requirements that could help speed up the Company Information Management process, supporting the work of the BIM Manager. It was decided to follow the ISO Standard so as to collect appointing and appointed parties requirements in the same document. From this decision derives the choice of naming the document 'Exchange' Information Requirements and not 'Employer', as explained in the previous sub-chapters. This chapter's focus is therefore entirely on the EIR template, leaving the OIR, AIR, and PIR models for a possible future development. This work is intended for company use and was purposely left unspecific so that could be adapted to different projects and used in countries with different standards. The Requirements and Standards in the documents are to be intended as an example. The BIM Manager, being responsible of the entire process, fill in the EIR with the project related standards and requirements, customizing each document. A complete template is attached in Appendix 1; in this subchapter several screenshots are included to better explain the document in its parts.

The template was developed in Excel, to be easy to fill and share with other stakeholders. The idea behind using this format was to support the increase of digital processes with digital signatures instead of paper. To support the transition process, however, the EIR might also be exported in .pdf and printed. The document was developed to achieve the best practice suggested by the standard analysis before. Each document created for this work is related to the developed Workflow (see Chapter 3). As illustrated in the Workflow, the gathered requirements constitute the basis for the development of the following BEP (5.2). The structure of the document is divided into five sections, each corresponding to an Excel schedule: Project general information, Applicable Standards, Technical Information, Information Management, and Plan of Work that will be presented in individual sections immediately bellow.

4.2.1. General Information

The first section contains general information about the project and a brief explanation of the goals, i.e. everything needed to introduce the project to the stakeholders (Table 11). The Plan of Work can be compiled according to the standards or chosen among the many available on the Internet. For the sake of work coherence, the developed Workflow was chosen as previously explained.

Table 11 – EIR General Information

General Information	
Company name	
Project name	
Project code	
Project goals	
Project address	
Plan of work	Developed Workflow

In the second part of the first schedule, the stakeholders' contacts are listed. Having all contacts enumerated in one document is vital to enable first-grade communication between stakeholders. A colour has been assigned to each supervisor, so as to facilitate identification of roles, responsibilities, and deliverables of each stakeholder, as well as processes and documents (Table 12).

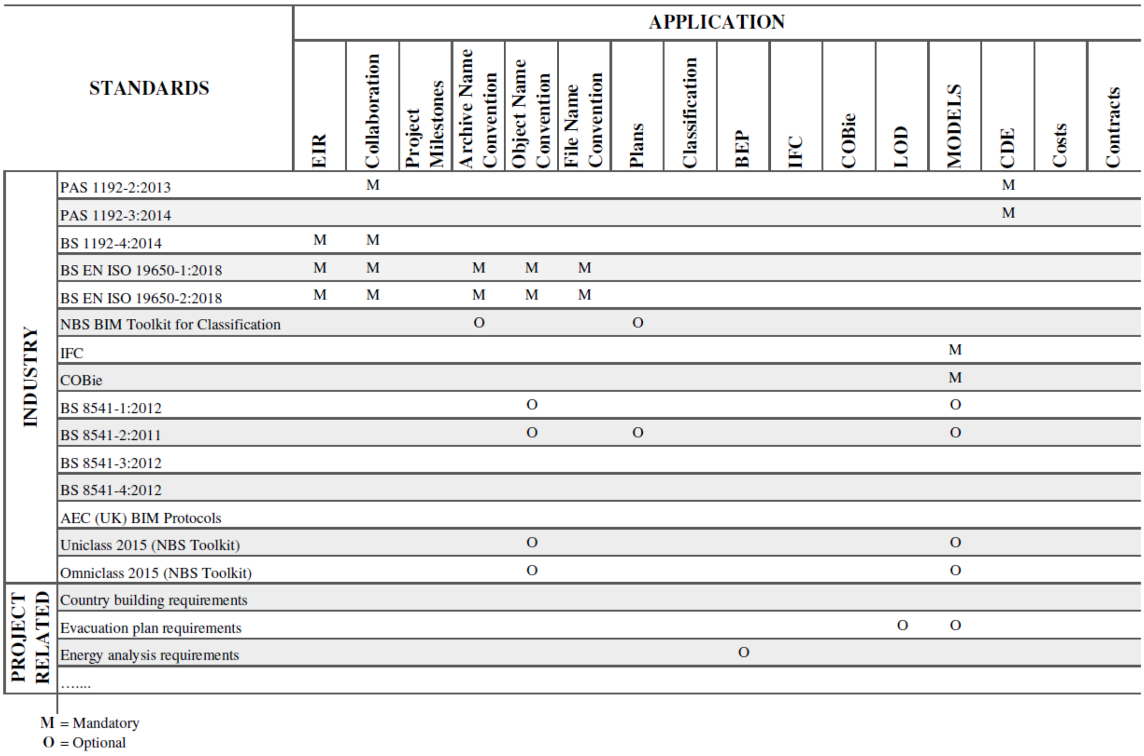
Table 12 – EIR Stakeholders' contacts

Stakeholders' Contacts	
Client/Owner	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
BIM Manager	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:

4.2.2. Applicable Standards

In this second section all the requested Standards for the project are listed. For each possible application, the BIM Manager could evaluate if the Standard is applicable or not and if it is mandatory or requested (Table 13). Once again, the listed Standards and the presented appropriate evaluation are by mere way of example. From this section, the document starts collecting Standards requirements from all parties involved in the project. Standards are also required, to make cooperation efficient and bring coherence to the project.

Table 13 – EIR Applicable Standards



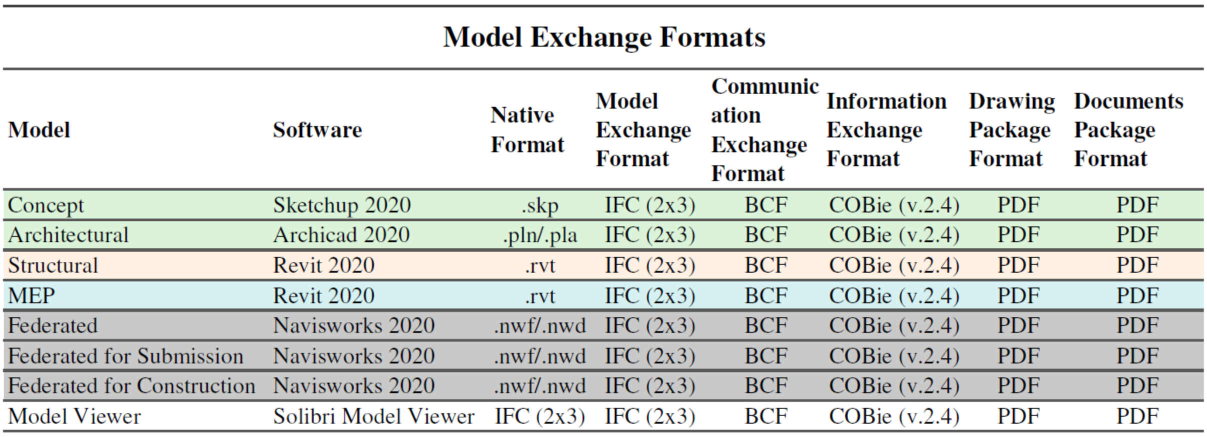
STANDARDS		APPLICATION															
		EIR	Collaboration	Project Milestones	Archive Name Convention	Object Name Convention	File Name Convention	Plans	Classification	BEP	IFC	COBie	LOD	MODELS	CDE	Costs	Contracts
INDUSTRY	PAS 1192-2:2013		M												M		
	PAS 1192-3:2014														M		
	BS 1192-4:2014	M	M														
	BS EN ISO 19650-1:2018	M	M		M	M	M										
	BS EN ISO 19650-2:2018	M	M		M	M	M										
	NBS BIM Toolkit for Classification				O			O									
	IFC													M			
	COBie													M			
	BS 8541-1:2012					O								O			
	BS 8541-2:2011					O		O						O			
	BS 8541-3:2012																
	BS 8541-4:2012																
	AEC (UK) BIM Protocols																
	Uniclass 2015 (NBS Toolkit)					O								O			
	Omniclass 2015 (NBS Toolkit)					O								O			
PROJECT RELATED	Country building requirements																
	Evacuation plan requirements												O	O			
	Energy analysis requirements									O							
	…….																

M = Mandatory
O = Optional

4.2.3. Technical Information

This section is mainly focused on technical details such as exchange format, model coordinates, general requirements of Level of Development and proposed parameters for Operational and Maintenance phase by the Facility Manager according to project needs. This part is also fundamental to enable work coherence and an excellent communication between discipline teams and stakeholders. In this section, the BIM Manager collect the task team requirements and gather the information about the software chosen by each team; he may also decide to employ just one authoring tool, so as to facilitate the exchange. As shown in the following image (Table 14), the native format of each software is listed; then, a specific open exchange format is requested for each type of deliverable. As in the first section, the task teams' colour palette is used to facilitate their identification.

Table 14 – EIR Model Exchange Formats



Model Exchange Formats

Model	Software	Native Format	Model Exchange Format	Communication Exchange Format	Information Exchange Format	Drawing Package Format	Documents Package Format
Concept	Sketchup 2020	.skp	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Architectural	Archicad 2020	.pln/.pla	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Structural	Revit 2020	.rvt	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
MEP	Revit 2020	.rvt	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Federated	Navisworks 2020	.nwf/.nwd	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Federated for Submission	Navisworks 2020	.nwf/.nwd	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Federated for Construction	Navisworks 2020	.nwf/.nwd	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Model Viewer	Solibri Model Viewer	IFC (2x3)	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF

In the same schedule, the chosen CDE platform is presented. The CDE was selected by the Client and the BIM Manager. Once the platform has been evaluated and selected, the use of the CDE core structure is requested – as explained in PAS 1192-2 (British Standards Institution, 2013). An elucidation of each folder content is provided to support the stakeholders' use of CDE (Table 15).

Table 15 – EIR CDE Platform and Structure

CDE Platform	
Autodesk 360	
Main Folder Structure	**Content**
Work In Progress (WIP)	Contains unapproved information provided by each team or organisation for their in-house design team use only. A supplementary section may be used to hold additional information for contractors.
Shared (comprehensive of client shared area)	Contains checked, reviewed and approved information ready to be used by other task teams, organisation and stakeholders as reference for their design. Once the information is checked, it is placed in the client area awaiting approval from the Client or their representative (BIM Manager).
Published	Contains the approved or accepted information by the Client, and it is ready to be used for authority submission, tender or construction.
Archived	This folder is used to store information and record of the projects for future uses.
CDE ownership should be shared between three people	

Model's Coordinates are also provided as a fundamental requirement for the creation of the Federated model in order to assemble it without any position displacement caused by incorrect coordinates (Table 16).

Table 16 – EIR Coordinates

Coordinates	
Survey Coordinates	23°N 15' 56"
Model Coordinates	0.0.0

In the end – always following the task teams' colour palette – all model elements are listed to be analysed by the BIM Manager. This list needs the teams’ final Level of Development. To identify the LOD classification, the BIM Forum Specification Part 1 was used and an LOD description was provided to support the choice. The hereby chosen LOD and classification were used only as an example. The Client and the BIM Manager will choose the required LODs tailoring them according to the project’s needs.

4.2.4. Information Management

The fourth section focuses on the Information Management, with particular regard to roles and responsibilities, data segregation, security, collaboration, and issues management.

As stated in sub-chapter 2.1.1, once roles are identified and competencies assessed, it becomes necessary to identify each role's responsibility. In Table 17 (again coloured according to the concurred workflow palette) to each role a task is assigned. These deeds are taken from the developed Workflow, same as per the stakeholders involved.

Since only one person is ultimately responsible for each actions and model but several other roles could be involved, an 'R' was assigned to the responsible, and a 'C' was assigned to the contributing roles – e.g. the BIM manager has the responsibility to collect the stakeholders' requirements and write them down in the BEP, so an 'R' was assigned to him in the BEP column; the Client/Owner, the Lead Architect, the structural engineer, the MEP engineer, the main Contractor and the Facility Manager were instead attributed a C.

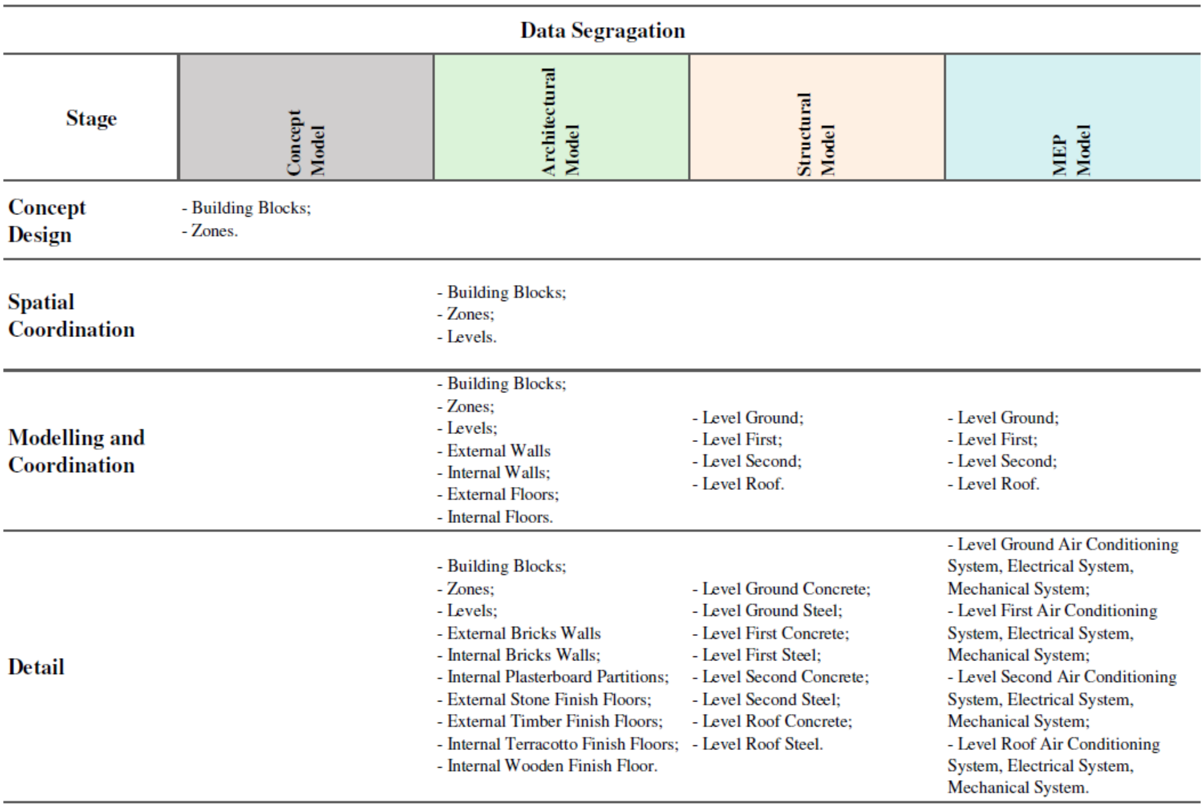
Table 17 – EIR Roles and Responsibilities

Role	Responsabilities																																			
	BIM Competencies Matrix	Project's team members maturity level assessment	OIR	AIR	PIR	EIR	BEP	Concept Model	Coordinate Supervise and Manage Processes	Settle and Coordinates Meetings	Coordinate and Supervise BIM Coordinators	Coordinate and Supervise Discipline Task Team	Architectural Model	Structural Model	MEP Model	Architectural Schedules Quantities Details Costs	Structural Schedules Quantities Details Costs	MEP Schedules Quantities Details Costs	Provide Specific Model Objects	Object's Library	Clash Detection Architectural Model	Clash Detection Structural Model	Clash Detection MEP Model	Quality Assurance Architectural Model	Quality Assurance Structural Model	Quality Assurance MEP Model	Clash Detection Federated Model	Quality Assurance Federated Model	Validation Federated Model	Clash Detection Federated Model for Submission	Quality Assurance Federated Model for Submission	Validation Federated Model for Submission	Clash Detection Federated Model for Construction	Quality Assurance Federated Model for Construction	Validation Federated Model for Submission	Shop Drawings
Client/Owner	C	C	C	C	C	C	C	C					C																							
BIM Manager (Architect)	R	R	R	R	R	R	R		R	R	R									R							R	R	R	R	R	R	R	R	R	
BIM Coordinator **Architects** Task team												R	C			R				C	R			R												
Architect Designer Team Leader					C	C	C	R					R			C				C																
BIM Coordinator **Structural Engineers** Task team												R		C			R			C		R			R											
Structural Engineer Team Leader					C	C	C							R			C			C																
BIM Coordinator **MEP Engineers** Task team												R			C			R		C			R			R										
MEP Engineer Team Leader					C	C	C								R			C		C																
Contractor Main					C	C	C																										C	C		R
Sub-Contractor																																	C	C		R
Facility Manager				C	C	C	C						C																				C	C		R
Supplier 1																			R	C																
Supplier 2																			R	C																

R = Responsible
C = Contribute

With regards to data segregation (Table 18), another table was developed according to the three models – Architectural, Structural and MEP – that are going to be part of the Federated one. To each model a different level of fragmentation was assigned, according to the workflow Stages and the type of information needed. The segregation levels inserted in the table are just an example.

Table 18 – EIR Data Segregation



Data Segragation

Stage	Concept Model	Architectural Model	Structural Model	MEP Model
Concept Design	- Building Blocks; - Zones.			
Spatial Coordination		- Building Blocks; - Zones; - Levels.		
Modelling and Coordination		- Building Blocks; - Zones; - Levels; - External Walls - Internal Walls; - External Floors; - Internal Floors.	- Level Ground; - Level First; - Level Second; - Level Roof.	- Level Ground; - Level First; - Level Second; - Level Roof.
Detail		- Building Blocks; - Zones; - Levels; - External Bricks Walls - Internal Bricks Walls; - Internal Plasterboard Partitions; - External Stone Finish Floors; - External Timber Finish Floors; - Internal Terracotto Finish Floors; - Internal Wooden Finish Floor.	- Level Ground Concrete; - Level Ground Steel; - Level First Concrete; - Level First Steel; - Level Second Concrete; - Level Second Steel; - Level Roof Concrete; - Level Roof Steel.	- Level Ground Air Conditioning System, Electrical System, Mechanical System; - Level First Air Conditioning System, Electrical System, Mechanical System; - Level Second Air Conditioning System, Electrical System, Mechanical System; - Level Roof Air Conditioning System, Electrical System, Mechanical System.

On the CDE data security, a table was developed showing the folder core structure of the CDE according to PAS 1192-2 (British Standards Institution, 2013), with other sub-folders contained in the main ones. The project roles are listed in the rows. Then letter 'A' was assigned to the stakeholders who have access to the specific sub-folder (Table 19). This table is useful to map folders' access and keep track of those to whom information is accessible. If throughout the project lifecycle a change in access permission is needed, the document needs to be updated and republished after the Client's approval. Only the folders of the CDE core structure are mentioned here. Sub-folders contained in each directory will inherit the permission. This table could be customised by the BIM manager adding inside each main folder other folders required, like one directory specific for Communications in the Shared folder.

Table 19 – EIR Data Security

CDE Data Security																				
	WIP					Shared						Published				Archived				
Role	Architectural	Structural	MEP	Contractor	Facility Management	Client Area	Magnager Area	Federated Model	Drawings	Documents	Contracts	Authorities Submissions	Published Drawings	Published Model	Published Documents	Federated Model	Drawings	Documents	Contracts	Submission to Authorities
Client/Owner						A					A	A	A	A	A	A	A	A	A	A
BIM Manager (Architect)						A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
BIM Coordinator Architects Task team	A							A	A	A		A	A	A	A					
Architect Designer Team Leader	A										A									
BIM Coordinator Structural Engineers Task team		A							A	A		A	A	A	A					
Structural Engineer Team Leader		A									A									
BIM Coordinator MEP Engineers Task team			A						A	A		A	A	A	A					
MEP Engineer Team Leader			A								A									
Contractor Main				A							A	A	A	A	A					
Sub-Contractor				A																
Facility Manager					A				A	A	A		A	A	A					

A = Access

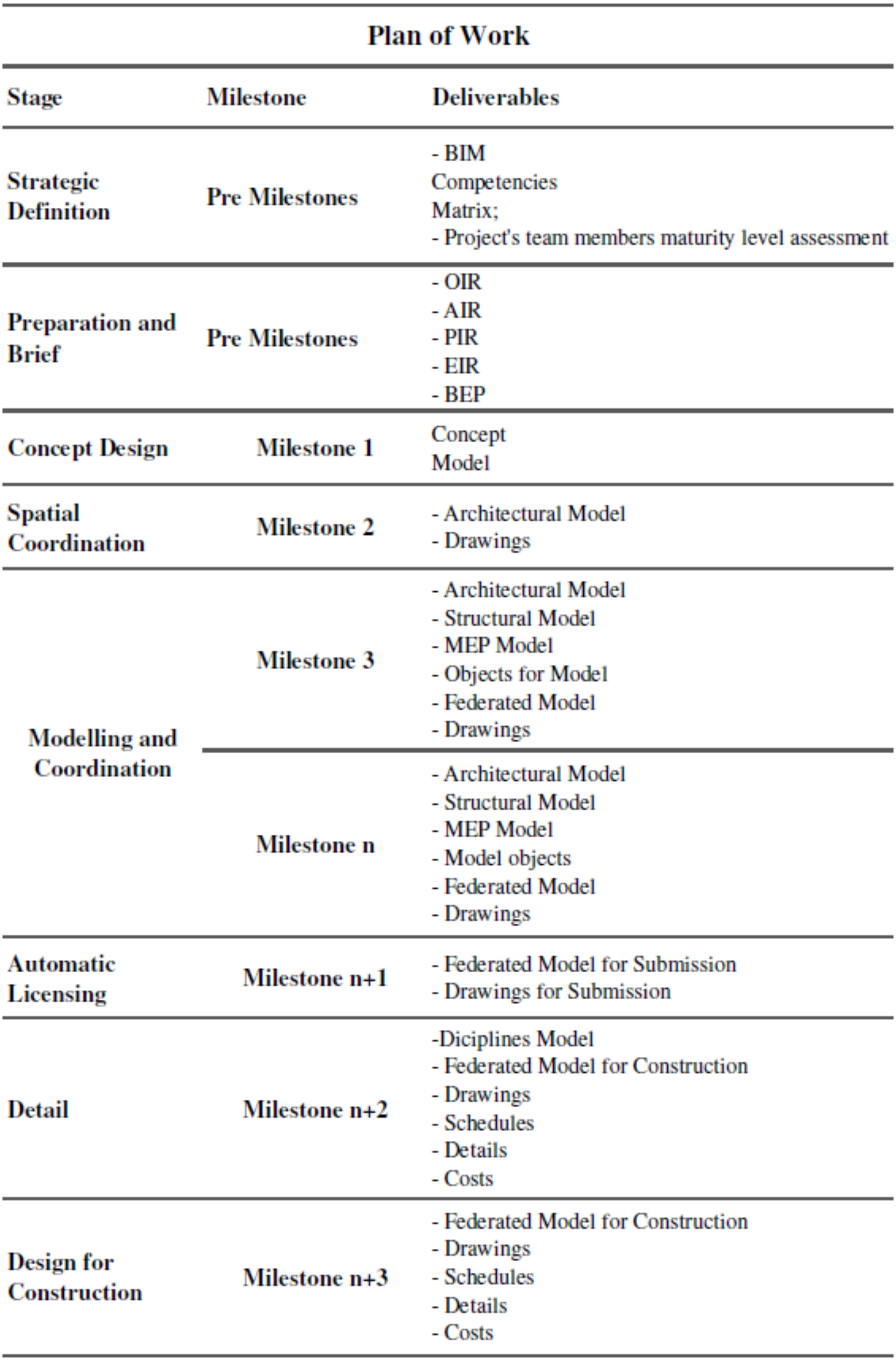
4.2.5. Collaboration and Issues Management

The project is based on IPD methodology and a collaborative environment is settled. The BIM Manager receives daily information from BIM Coordinators, Contractor and facility manager, keeping the project's progresses and issues under control. The BIM Coordinator for his part runs weekly internal task team clash detection and quality control checks. Every Friday at 5.00 pm the disciplines models must be uploaded in the CDE shared folder – 'Federated Model' sub-folder – for the BIM Manager to check. Every two weeks, the BIM Manager runs a clash detection and quality control check of the Federated model. After the clash detection, a report of issues is sent to the BIM Coordinators and a workshop takes place. During the meetings, the Coordinators should provide solutions for the reported issues.

4.2.6. Plan of Work

In the fifth section, the requested deliverables are listed for each Milestone according to the project stages (Table 20). The deliverables in the document are used as an example. The BIM Manager, on the Client's behalf, will customise them according to the project needs and the Information needed from all the stages. Milestones and stages are following the Workflow. More specific deliverables will be cited in the BEP.

Table 20 – EIR Plan of Work



Plan of Work

Stage	**Milestone**	**Deliverables**
Strategic Definition	**Pre Milestones**	- BIM Competencies Matrix; - Project's team members maturity level assessment
Preparation and Brief	**Pre Milestones**	- OIR - AIR - PIR - EIR - BEP
Concept Design	**Milestone 1**	Concept Model
Spatial Coordination	**Milestone 2**	- Architectural Model - Drawings
Modelling and Coordination	**Milestone 3**	- Architectural Model - Structural Model - MEP Model - Objects for Model - Federated Model - Drawings
	Milestone n	- Architectural Model - Structural Model - MEP Model - Model objects - Federated Model - Drawings
Automatic Licensing	**Milestone n+1**	- Federated Model for Submission - Drawings for Submission
Detail	**Milestone n+2**	-Diciplines Model - Federated Model for Construction - Drawings - Schedules - Details - Costs
Design for Construction	**Milestone n+3**	- Federated Model for Construction - Drawings - Schedules - Details - Costs

5. BIM EXECUTION PLAN

The BIM Execution Plan is a managerial and business document, essential to achieve a full BIM Level 2 (Figure 3). Once the contract has been awarded, representatives from all the primary teams (owner, architects, engineers, facility manager and main Contractor) produce the BEP as a direct response to the EIR through a series of planning meetings; after the initial draft, it is then updated at every stage. The BEP is essentially a contractual agreement that defines how the project will be managed and executed, how the information will be exchanged, how the model will be updated and using which platform. It establishes clear roles and responsibilities, as well as the communication methods and the expected deliverables; it also determines the RACI (Responsible, Accountable, Consulted, Informed) matrix to assign responsibility throughout the project. Once the initial goals are settled, the BIM Manager prepares them for the submission. The document also comprises information about the technology used, the level of development, which data should be entered into the model, and how to pass it on to the construction and operational phases. In big projects, which may take years to conclude, it is especially important to provide regular software updates, at least every two or three years. In this manner, you could avoid any future interoperability issues, especially if new contractors or suppliers are added to the team, thus ensuring that the BIM models be accessible for a long time. Provided that is always advisable to include a provision to use the same authoring tool, when this is not possible it is nevertheless suggested to at least envisage a scenario in which data need to be exchanged among different pieces of software. A federated model, containing models from all disciplines submitted in IFC format, is to be encouraged for the purpose of interoperability, clash detection and QA/QC. It could also be useful to agree to extract that information according to the COBie (Construction Operations Building information exchange) scheme, establishing a common nomenclature ad naming standard. Moreover, it is crucial to establish a common geo-referenced system and a reference point to link models with each other correctly and to export IFC without any information loss. For this purpose, it is desirable to establish problem-solving procedures to face issues that may occur during this exchange phase. Another essential part of the BEP is the establishment of a detailed Level of Development to be delivered at each Milestone. LOD must be specified as a requirement for the subsystem projects at different phases. In the first phase of the project, a LOD 200 model might be good enough for spatial coordination, but later on it will need to be improved to LOD 300 or LOD 400, according to the project needs. Specifying the LOD number in each phase is also important to avoid unnecessary modelling effort; even if the model is well defined, contractors could modify and adapt it during the construction phase. During these phases, it is crucial to keep the model updated.

5.1. Literature Review

In the last few years, due to the development of a more collaborative and open work environment, concerns were raised about security. To deal with to these concerns, the UK BIM Task Group developed PAS 1192-5:2015: ‘Specification for security-minded building information modelling, digital built environments and smart asset management.’ This document highlights some issues with the information security of BIM projects and outlines some procedures that could be adopted and incorporated inside the BEP.

Setting out regulations is crucial in the BIM process to avoid lack of information, ambiguity, fragmentation, data overload, and information doubling.

As it will be better explained later on, each system analysed in the previous chapter for the Information Requirements (4) developed its personal BEP concept. Nevertheless, all of them agree on having two BEP documents: one before and one after contract (the names of which are different per each Standard).

5.1.1. American System

As continuation of the BIM Project Execution Planning Procedure after the Owner's Project Requirements (OPR) (4.1.1), the National BIM Standards established the development of the BIM Project execution Plan (BPxP). As per the National BIM Guide for Owners (National Institute of Building Science), a BIM Project Execution Planning Guide was prepared by the Pennsylvania State University (Messner, Anumba, et al., 2019), Version 2.2. This guide uses a four-steps procedure to establish the BPxP according to the BIM Project Execution Planning Procedure (Figure 23). The document also identifies two phases: a proposal stage BPxP and a final BPxP.

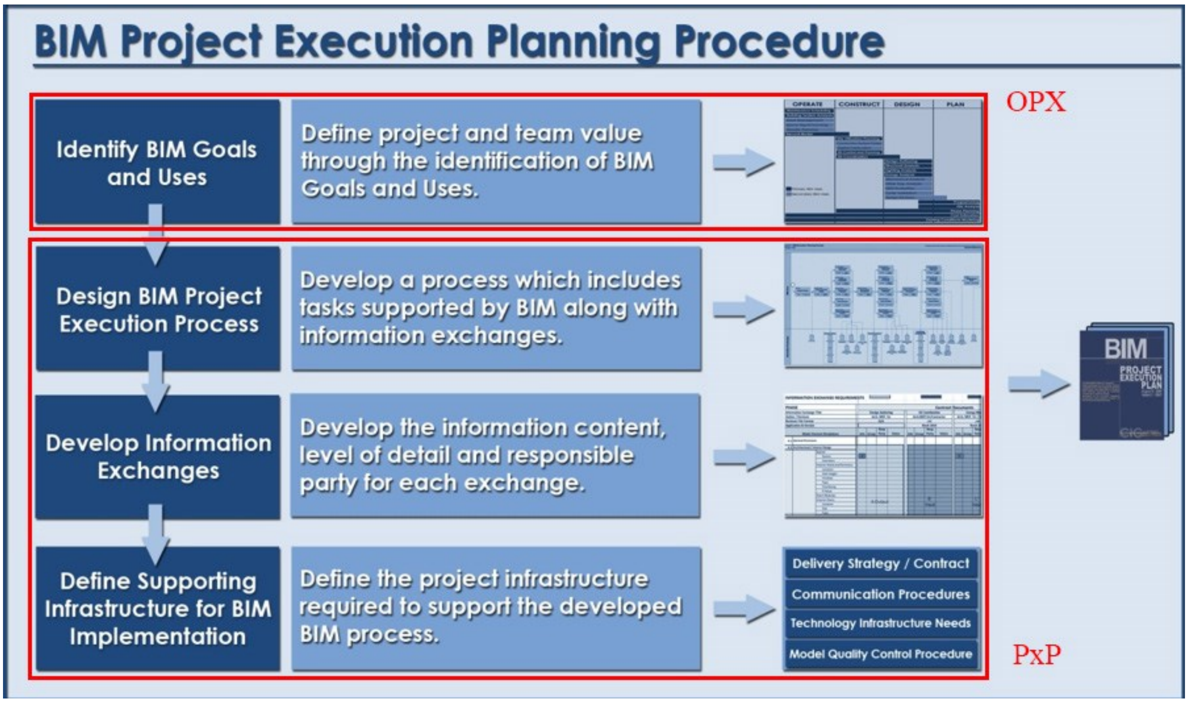


Figure 23 – BIM Project Execution Planning Procedure – adapted from (Messner, Anumba, et al., 2019)

The first step is overlapped and integrated by the OPR (4.1.1), which defines the BIM uses and the project goals. During the second stage, a process map procedure is developed, further splitting the process into two phases: phase one consists of high-levelling the map to identify the interaction between the BIM uses and to clarify the work processes and the other teams' performances. Once the general map is determined, a second detailed map is drawn by the task team members, specifying the complete procedure needed to complete the work. The third step is about the Information Exchange and is required to understand the information content, its route into the process map, who is going to produce the information, to whom it will be addressed, and how it will be exchanged. These requirements could be easily managed with an Excel worksheet. The fourth and last stage is to define the supporting infrastructure for BIM implementation, which is to say designing and creating a framework to support the project deliveries and the contract specification as per the communication procedures, the technology to be used, and the quality control of the model information. According to the BPxP process, once the document is completed, it should address at least these facts:

- Project information
- Key project contacts
- Project goals and BIM uses
- Organisational roles and staffing
- BIM project execution plan overview
- BIM process design
- BIM information exchanges
- BIM and facility data requirements
- Collaboration procedures
- Technological infrastructure needs
- Model structure
- Quality control
- Project deliverables
- Delivery strategy and contract

This procedure is designed to meet the National BIM Standard – United States (NBIMS-US) Version 3: the project team could fill in step 3 (Information Exchange) without establishing a custom standard for the company or the project, but following the industry exchange standard. According to this, a firm could integrate its own customised workflow with the BIM National Procedure (Figure 24).

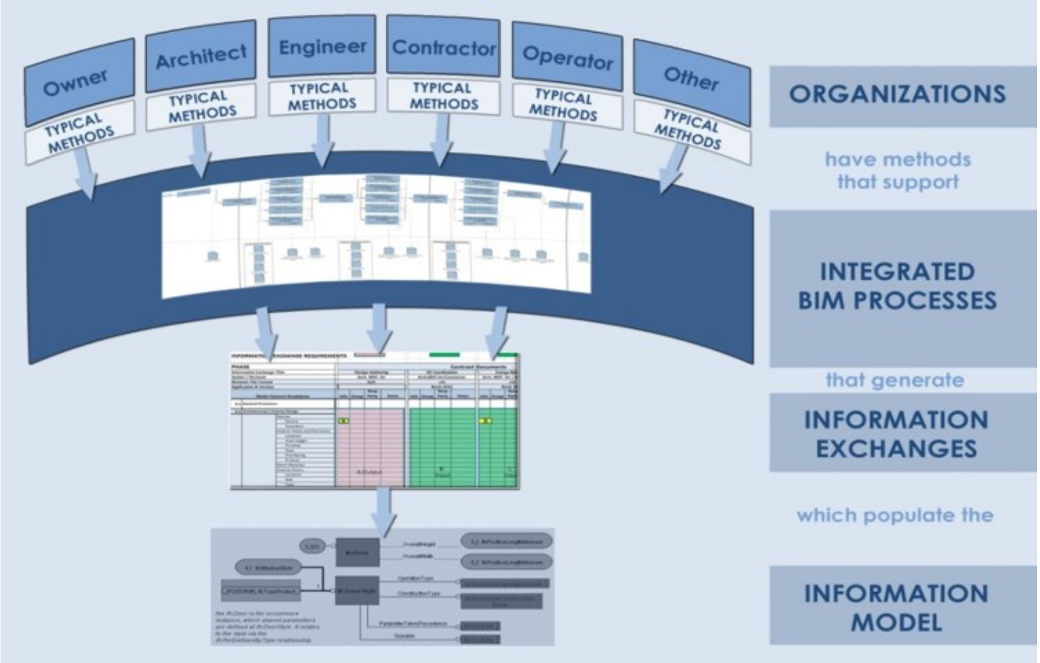


Figure 24 – BIM Project Execution Planning Concept (Messner, Anumba, et al., 2019)

5.1.2. British Standard (BS-PAS)

BS PAS 1192-2:2013 propose to draft the BIM Execution Plan as a document based on the EIR for managing the delivery of the project. This Specification identifies two phases of the BEP that actually become two separate but interconnected documents: the **pre-contract BEP** and the **post-contract BEP** (Figure 25). It is further possible to follow the guidelines of the CPIx to develop these documents. The first one is prepared by the supplier perspective and includes all the requirements settled out in the EIR plus:

- the project implementation plan (PIP), to assess the capability and competence of potential suppliers along with quality documentation;
- project goals for collaboration and information modelling;
- major project milestones consistent with the project program and the project information model (PIM) deliverable strategy.

Once the contract award is defined, the Supplier has to produce the post-contract BEP which will include, as the first pre-contract one, the Employer's requirements plus the Specification about roles and responsibilities, milestones and deliverables, strategy, software to use, information exchange etc.

The post-contract BEP is a document that can facilitate the project delivery, so it must include a section of planning. This section is covered, according to PAS 1192-2:2013, by the Master Information Delivery Plan (MIDP) and the Task Information Delivery Plans (TIDP) (Figure 25). The MIDP is an annex document to the post-contract BEP based on a series of TDIPs prepared by each task teams to set out the responsibility for each specific information deliverable. The project delivery manager develops the MIDP according to the EIR and the TDIPs; it sets out for each stage which information should be delivered, by whom, and according to which protocol.

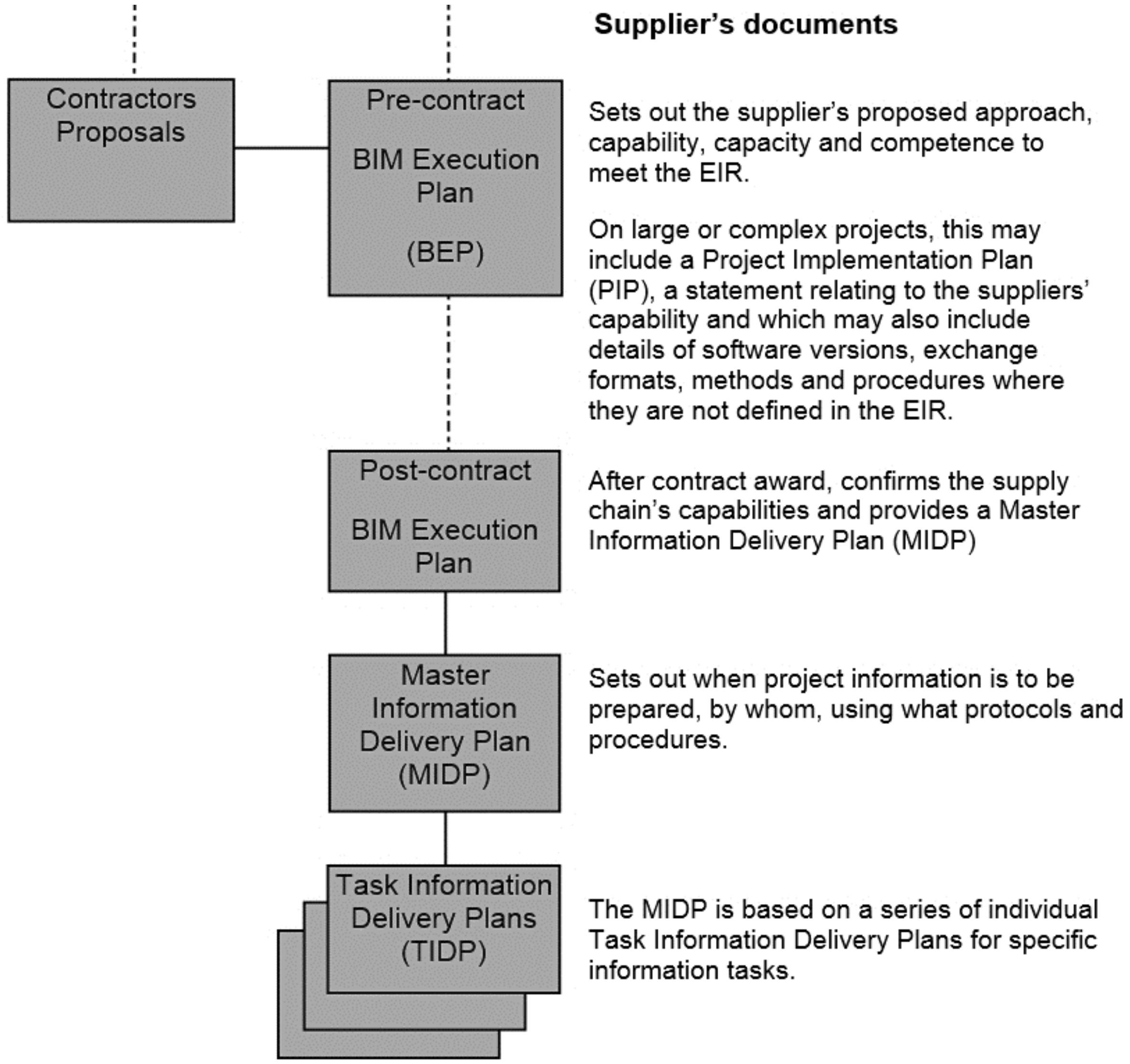


Figure 25 – Contractual documents' relationships according to BS PAS 1192-3:2014 (Design Buildings Wiki, 2020b)

5.1.3. International Standard (ISO)

According to ISO 19650-2, the BEP is part of a set of documents produced by the lead appointed party on behalf of (or in collaboration with) the delivery team. The Standard identifies two purposes for the BEP in supporting the tendering process: making sure that the delivery team is capable of satisfying the appointing party's requirements and providing a delivery plan to produce, manage and exchange project information. ISO 19650-2 does not divide the BEP in two documents, as the PAS 1192-2:2013 does. It addresses the issue nonetheless, though, designating a **pre-appointment BEP** and a **proper BEP** (Figure 26), the latter being the updated version of the former. According to the standard clause 5.3.2, the pre-appointment BEP should contain at least seven key information management:

- Provide the individuals' details to assure their competencies to fulfil the requirements of the project delivery;

- Propose a project delivery strategy – meet the Exchange IR, set project goals and objectives, delivery teams setting and their collaboration;
- Propose the federation strategy adopted by the delivery team;
- The delivery team's responsibility matrix specifying the required deliverables for each element;
- Proposed amends to the project's information methods and procedures;
- Proposed amends to the project's information standard and exchange;
- Proposed software schedules and IT solutions;

The pre-appointment BEP should be revised and updated during the period between the appointment and the contract sign becoming the BEP.

As for PAS 1192-2:2013, the delivery team should produce a Task Information Delivery Plan (TIDP) setting out the tasks to support the lead appointed party in the managing and coordinating of all the task teams with the development of the Master Information Delivery Plan (MIDP).

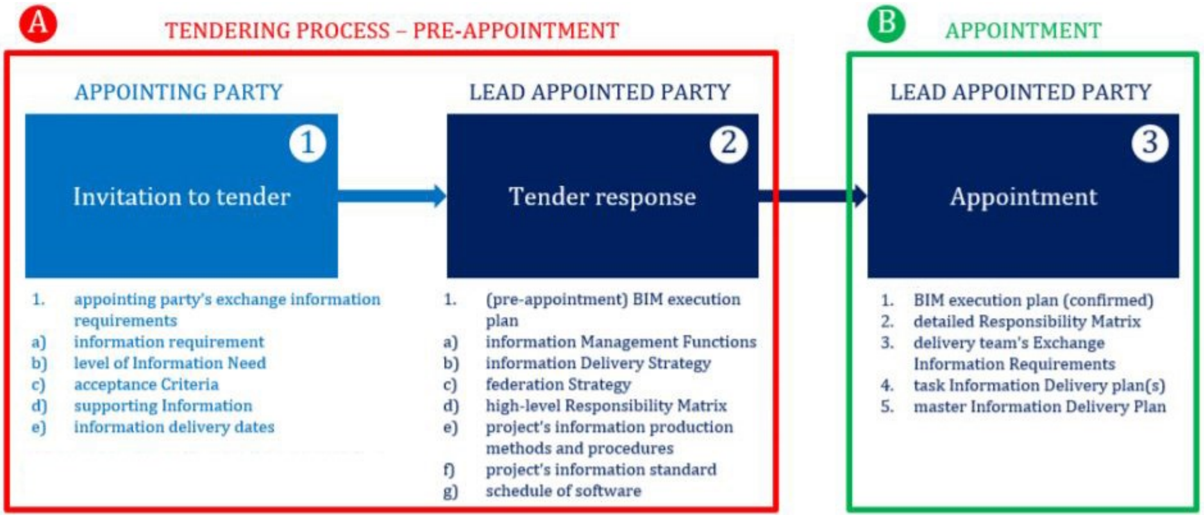


Figure 26 – The Information workflow according to ISO 19650-2 – adapted from (British Standard Institution, 2019)

5.1.4. Italian System

As per the Capitolato Informativo, the Italian System will emulate the PAS Standard workflow, only translating the terms: the pre-contract BEP becomes the offerta di Gestione Informativa (oGI), and the post-contract BEP the piano di Gestione Informativa (pGI) (Figure 27). These documents are defined in the UNI 11337-6 inside the Capitolato Informativo specifications. At the moment, though, there are no specific standards for the oGI and the pGI. The UNI proposed a CI structure, with the suggestion to request the supplier to produce the oGI before the tender and the development of the pGI after the contract award; still, it does not yet propose a solid structure for them. It is also difficult, however, to find a template for the three documents. The UNI 11337-6, regarding the information exchange, asks the supplier to establish a table defining the procedures for the model validation, the deliverables, and the quality control of the process, by referring to the UNI 11337-5 for the desired level of coordination. It also suggests a possible nomenclature convention even without having a standardised system as in the

UK, where instead a naming convention was developed. In the section of the Capitolato Informativo, under the UNI standard, as per the PAS one, the use of a Common Data Environment is established, transposed in Italian as Ambiente di Dati Comuni (ACDat UNI 11337-1).

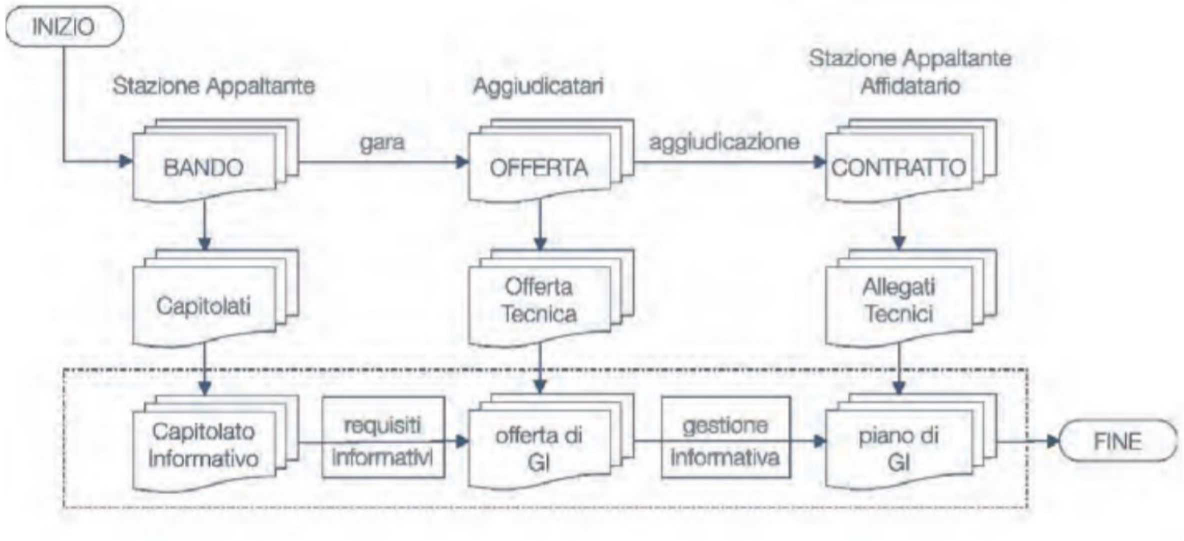


Figure 27 – Italian BIM process (De Gregorio, 2018)

5.1.5. Comparison between the four systems

As already mentioned in subchapter 4.1.5, the four systems agree on the three phases of the process with regards to the development of the Information requirements and the BEP. The standards agree it ought to be a constantly evolving document, growing at every stage of the process. Its requirements should be precisely defined, so as to avoid lack of information, information inconsistency, delivery delay, and exchange issues. Both the American System and the International Standard identify a unique BEP, that has to be preceded by a proposal stage before the tendering. The British and Italian ones, instead, call for two separate documents: one for the tendering procedure and one to be produced after the award. Despite this little difference, the final BEP consists in a similar document that carries the same purpose in all four systems (Table 21).

Table 21 – Listing Table for tender and contract award documents in various Systems - adapted from (Pavan, 2017)

Source	Owner/Client	Tender	Contract award
USA (NIBIMS)	BPxP (OPR)	BPxP (proposal stage)	BPxP (final)
UK (PAS)	EIR (Employer IR)	BEP (pre-contract)	BEP (post-contract)
ISO	EIR (Exchange IR)	BEP (pre-appointment)	BEP
ITA (UNI)	CI	oGI	pGI

5.2. Development of a BEP template

The previous sub-chapters delve into the importance of the BEP, suggesting a new proposal for the document. Research was also carried out on national Standards to identify the best practices. Although the market offers many examples of BEP templates and some platforms even support them, these often require licensing. Moreover, even though many platforms allow users to choose which Standard to follow, these are not easily personalised. The proposed template is explicitly made to be suitable for different projects in different countries; it was designed to provide a unique BEP document that could be modified and improved after the contract, as required by the American and ISO Standards. The development of a pre and post contract document was taken into account at the beginning. Still, then, the idea was rejected, so as not to replicate information inside files and so that CDE could speed up the procedure. For the same purpose, reiteration of already discussed and examined information in the BEP template is explicitly avoided. Improved topics, instead, (as per 'LOD') are included.

As regards the EIR template, the document is in Excel format, in order to give the BIM Manager the possibility to tailor it according to the project's needs and to easily share it with other actors. Since electronic document exchanges are always desirable, a digitally-signed excel format was adopted. The file may however also be exported in PDF and printed. Depending on the grade of customization of the template, it could be suitable for proper BEP or for internal use. This document drives and support the BIM Manager in the process of coordinating and setting up discipline task teams and stakeholders' duties. This file is in constant evolution throughout the entire project lifecycle, changing and adapting according to the needs.

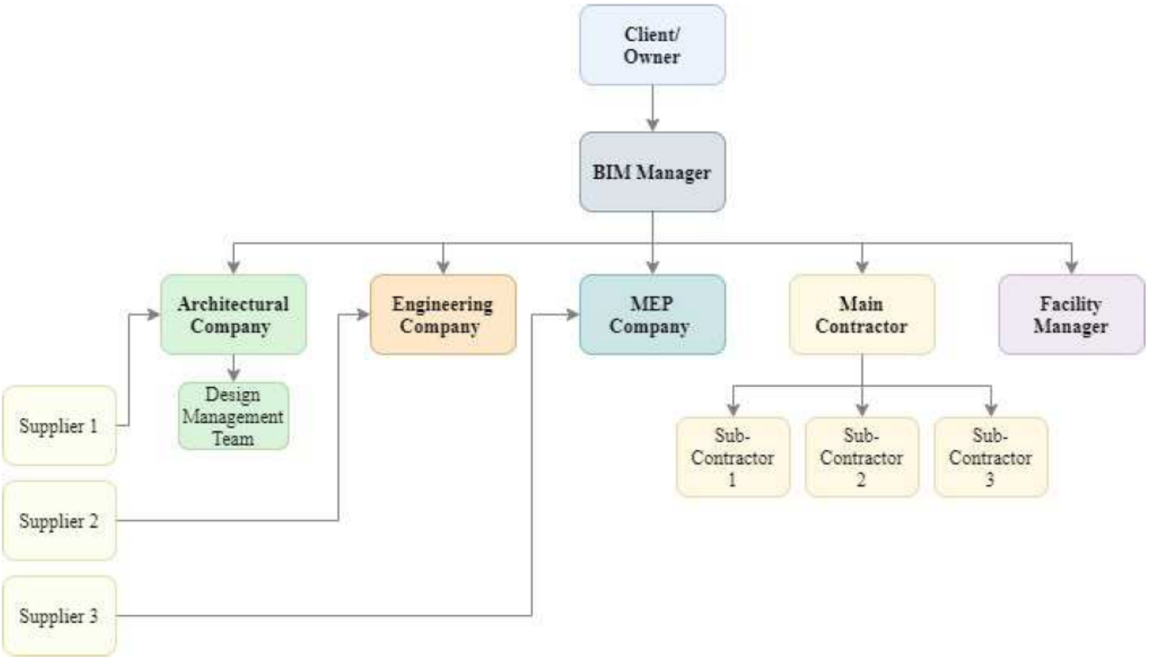
This work aims at producing a BEP template as the main document leaving, despite their importance, Master Information Delivery Plan and Task Information Delivery Plan for future development. Information inserted in the here provided BEP is to be considered as an example and should not be taken into account for project evaluation. The document is introduced in parts to allow a better comprehension; the complete template may be found in Appendix 2. The presented document is in its final version, modified after the validation process. As the previously produced materials, also the BEP is related and follows the developed Workflow (3); and the same goes for the colour scheme. As already mentioned, before drafting the BEP the BIM Manager settles a meeting between the main stakeholders to gather information and requirements.

The template is structured in eight sections corresponding to the same number of Excel sheets: Organigram, BIM Coordination, RACI matrix, Software, Name Convention, Object Library Parameters, LOD, and Project Milestones. These sections are presented in its specific subsection below.

5.2.1. Organigram

In this first section, the structure of the stakeholders and companies involved in the project is graphically explained (Figure 28). At the top of the organigram is the project's Client/Owner; immediately under him, the BIM Manager, who acts on his or her behalf during the entire lifecycle of the project. Under the BIM Manager control there are all the companies involved, such as the Architectural, the Structural, the Main contractor and the Facility Manager. The graph also illustrates if there is any stakeholder acting under the supervision of other contractors (sub-Contractors) or other external actor that provides companies and stakeholders with model objects or material (Suppliers).

Organigram



Contacts are available in the EIR

Figure 28 – BEP Organigram

5.2.2. BIM Coordination

The second section graphically explains the BIM Coordination process as the relationship between BIM actors and deliverables (Figure 29). At the top of the graph there is the BIM Manager, who is responsible for the entire process. Under him, the BIM Coordinators and the BIM Modellers for each involved discipline. A brief description of the BIM roles is also provided as legend. Next to the BIM roles – still under the BIM Manager’s control –are the Main Contractor and the Facility Manager. They produce several deliverables that are stored in the CDE. In the diagram, the core structure of the Common Data Environment is also represented, with its four main folders and the deliverable of which are contained inside.

Actions carried out by the BIM Manager and the BIM Coordinators are highlighted; they are responsible for running the Clash detection and making the Model Quality Control checks. Disciple Coordinators need to execute these tasks on their model weekly, while the Manager does the same on the Federated model every two weeks. Two weeks period is suggested taking into account that the right amount of Clashes detection to be defined will depend on the magnitude and the scale of the project.

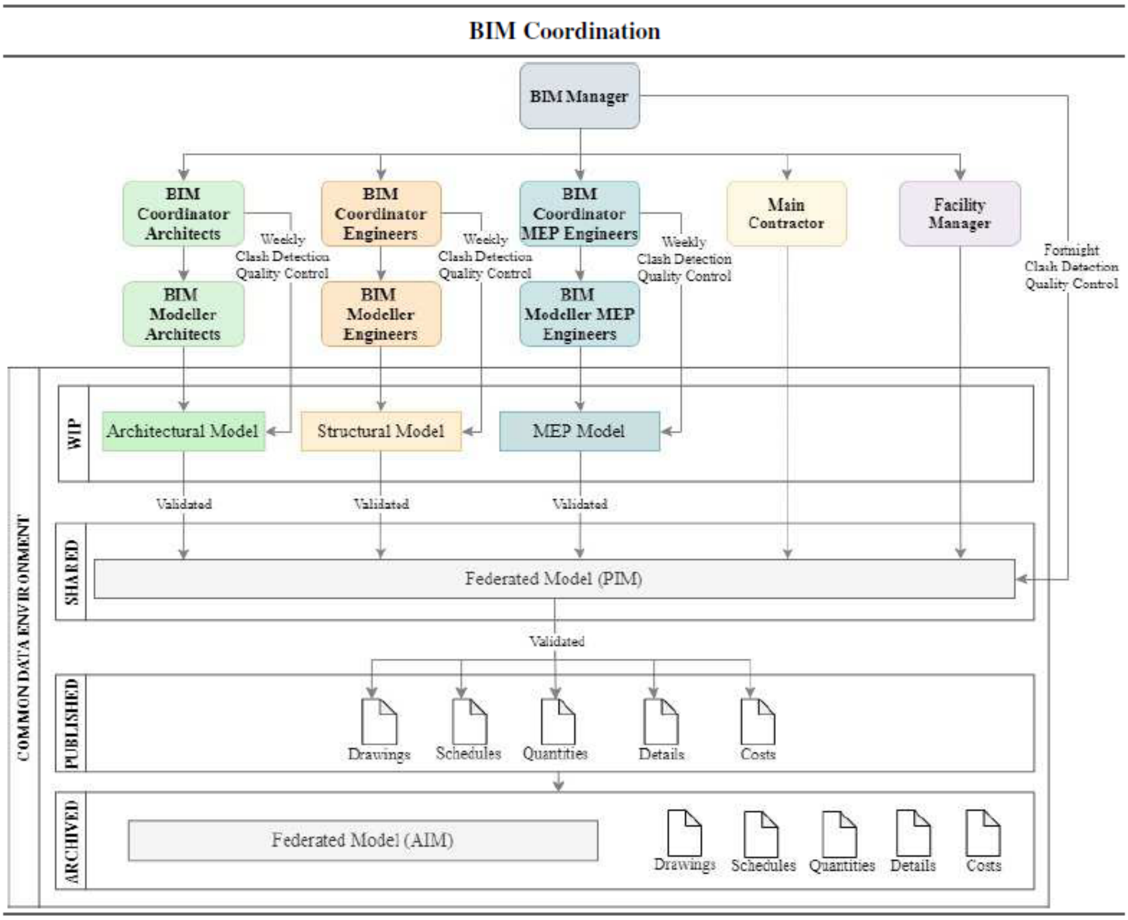


Figure 29 – BEP BIM Coordination

Immediately under the diagram, the Collaboration and the Issue Management procedure are explained as per the EIR document. As regards the CDE Data Security, instead, the reader is redirected to the EIR template, so as not to duplicate information, same as per 'Collaboration and Issues Management'.

5.2.3. RACI matrix

This matrix's name is an acronym for Responsible Accountable Consulted and Informed. A provided brief legend explains the meaning of these roles. This matrix is used to assign and track stakeholders' responsibilities throughout the project (Table 22). Each role can have several tasks to complete, according to the deliverables. Once roles and tasks are established, the matrix can be filled in. Each role is responsible of several tasks and each task can have more than one person responsible for it, albeit only one being held accountable. Moreover, stakeholders may be consulted or informed about the task process. An actor could be, at the same time, responsible and accountable for the same task – e.g. regarding the Clash detection of the Federated model, the BIM Manager is responsible for running it and it is also the person accountable for the task. The Client must be informed after the model validation.

Table 22 – BEP RACI matrix

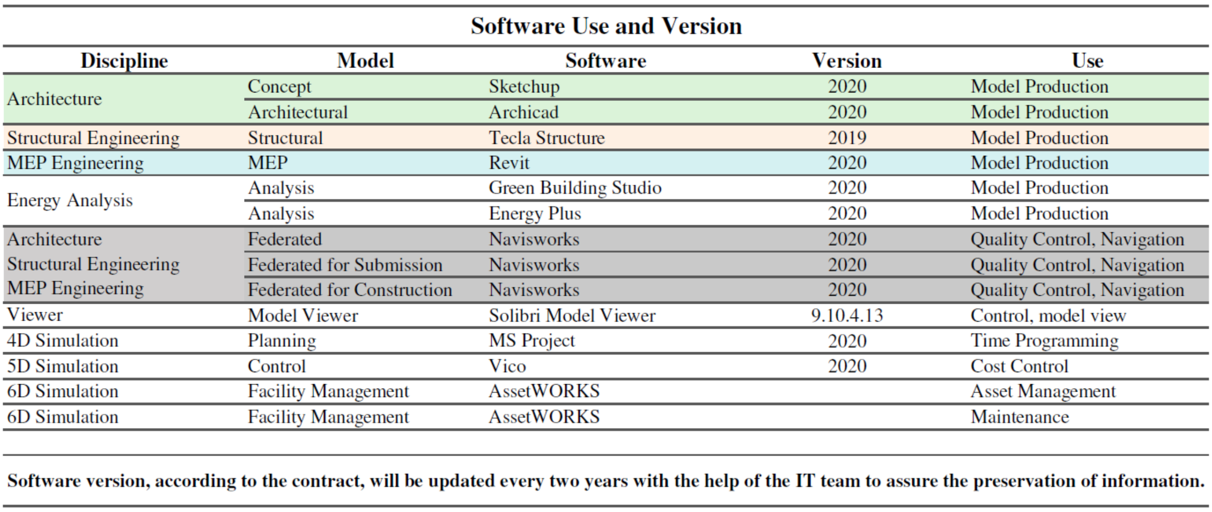
Role	Deliverable																								
	Concept Model	Architectural Model	Structural Model	MEP Model	Architectural Schedules Quantities Details Costs	Structural Schedules Quantities Details Costs	MEP Schedules Quantities Details Costs	Provide Specific Model Objects	Object's Library	Clash Detection Architectural Model	Quality Assurance Architectural Model	Clash Detection Structural Model	Quality Assurance Structural Model	Clash Detection MEP Model	Quality Assurance MEP Model	Clash Detection Federated Model	Quality Assurance Federated Model	Validation Federated Model	Clash Detection Federated Model for Submission	Quality Assurance Federated Model for Submission	Validation Federated Model for Submission	Clash Detection Federated Model for Construction	Quality Assurance Federated Model for Construction	Validation Federated Model for Submission	Shop Drawings
Client/Owner	C	I																I			I			I	
BIM Consultant										I	I	I	I	I	I	I	I		I	I		I	I	I	I
BIM Manager (Architect)	I	I	I	I	I	I	I		A	I	I	I	I	I	I	A/R	A/R	A/R	A/R	A/R	A/R	A/R	A/R	A/R	A
BIM Coordinator **Architects** Task team		C			A				C	A/R	A/R					C	C	I	C	C	I	C	C	I	R
Architect Designer Team Leader	R	A	C	C						I	I					I	I		I	I		I	I		
BIM Modeller **Architects** Task team		R			R					C	C														
BIM Coordinator **Structural Engineers** Task team			C			A			C			A/R	A/R			C	C	I	C	C	I	C	C	I	R
Structural Engineer Team Leader		C	A	C								I	I			I	I		I	I		I	I		I
BIM Modeller **Structural Engineers** Task team			R			R						C	C												
BIM Coordinator **MEP Engineers** Task team				C			A		C					A/R	A/R	C	C	I	C	C	I	C	C	I	R
MEP Engineer Team Leader		C	C	A										I	I	I	I		I	I		I	I		I
BIM Modeller **MEP Engineers** Task team				R			R																		
Contractor Main																						C	C	I	R
Sub-Contractor																						C	C	I	R
Facility Manager		C	C	C																		C	C	I	R
Supplier 1								R	R																
Supplier 2								R	R																

R Responsible = Assigned to complete the task or deliverable.
A Accountable = Has final decision-making authority and accountability for completion. Only 1 per task.
C Consulted = An adviser, stakeholder, or subject matter expert who is consulted before a decision or action.
I Informed = Must be informed after a decision or action.
A/R Accountable and Responsible

5.2.4. Software

The fourth section of the document enumerates the piece of software that are used in the project. Software are divided according to the discipline that adopts it and its related model; a brief explanation is also provided. In the example, the matter of the versioning was also addressed, providing for a version update every two years (Table 23).

Table 23 – BEP Software Use and Version



Software Use and Version

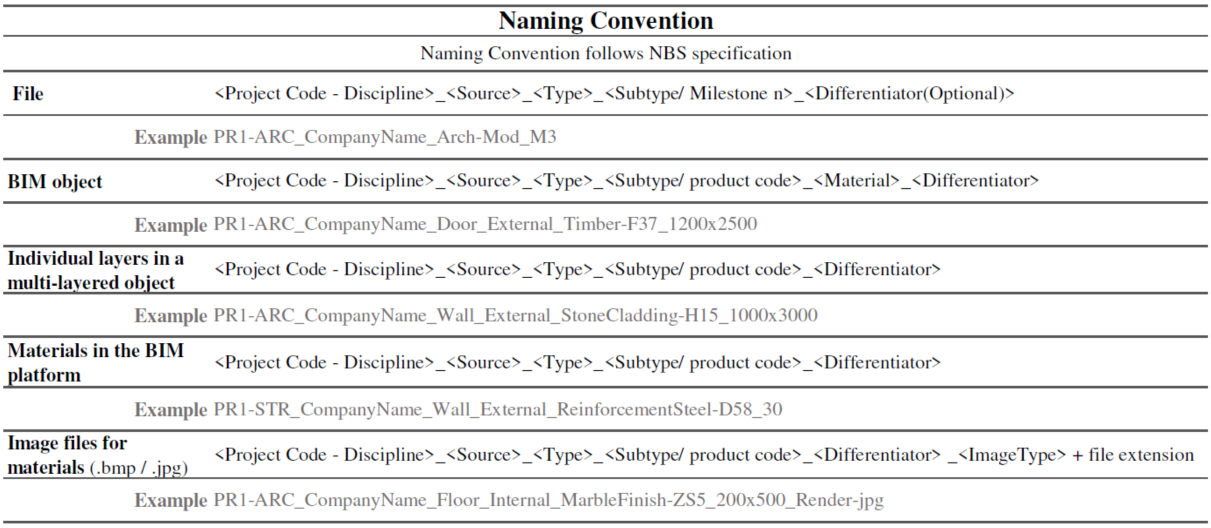
Discipline	Model	Software	Version	Use
Architecture	Concept	Sketchup	2020	Model Production
	Architectural	Archicad	2020	Model Production
Structural Engineering	Structural	Tecla Structure	2019	Model Production
MEP Engineering	MEP	Revit	2020	Model Production
Energy Analysis	Analysis	Green Building Studio	2020	Model Production
	Analysis	Energy Plus	2020	Model Production
Architecture Structural Engineering MEP Engineering	Federated	Navisworks	2020	Quality Control, Navigation
	Federated for Submission	Navisworks	2020	Quality Control, Navigation
	Federated for Construction	Navisworks	2020	Quality Control, Navigation
Viewer	Model Viewer	Solibri Model Viewer	9.10.4.13	Control, model view
4D Simulation	Planning	MS Project	2020	Time Programming
5D Simulation	Control	Vico	2020	Cost Control
6D Simulation	Facility Management	AssetWORKS		Asset Management
6D Simulation	Facility Management	AssetWORKS		Maintenance

Software version, according to the contract, will be updated every two years with the help of the IT team to assure the preservation of information.

5.2.5. Naming Convention

Establishing a Naming Convention is crucial for accuracy, collaboration and interoperability. In this template we chose the NBS naming convention, being of the most commonly used in the field (Table 24). An example of each naming is provided to help the user in the compilation. Examples are in light grey.

Table 24 – BEP Naming Convention – adapted from (NBS, 2017)



Naming Convention

Naming Convention follows NBS specification

File	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ Milestone n>_<Differentiator(Optional)>
Example	PR1-ARC_CompanyName_Arch-Mod_M3
BIM object	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ product code>_<Material>_<Differentiator>
Example	PR1-ARC_CompanyName_Door_External_Timber-F37_1200x2500
Individual layers in a multi-layered object	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ product code>_<Differentiator>
Example	PR1-ARC_CompanyName_Wall_External_StoneCladding-H15_1000x3000
Materials in the BIM platform	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ product code>_<Differentiator>
Example	PR1-STR_CompanyName_Wall_External_ReinforcementSteel-D58_30
Image files for materials (.bmp / .jpg)	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ product code>_<Differentiator> _<ImageType> + file extension
Example	PR1-ARC_CompanyName_Floor_Internal_MarbleFinish-ZS5_200x500_Render-jpg

5.2.6. Object Library Parameters

For the sake of collaboration and interoperability, the sixth section of this document was dedicated to the Object Library Parameters. The IFC schema is an open format used for the information exchange. IFC is a really useful schema for interoperability, but it needs to be well studied in order to be properly used. Each programme stores information in different places and it is crucial to understand where the information is registered so as to find it again at a later time. NBS provides a table explaining the correspondence between NBS specification, different pieces of software, and IFC schema (Table 25). On their website, it is also possible to download a plug-in to insert parameters specification inside the project file. Additionally, NBS already provides some settled parameters for the Operational and Maintenance phase but, if needed, the Facility Manager could add in this section other parameters according to project needs.

Table 25 – BEP Object Library Parameters – adapted from (NBS, 2017)

Object Library Parameters		
Object parameters follows the NBS specification		
NBS plug-in are available for Revit, Archicad and Vectorworks		
NBS parameters correspondence for Revit, Archicad and Vectorworks:		
Property Group	**Autodesk Revit**	**IFC, ArchiCad, Vectorworks, AECOsim**
IFC	IFC Parameters	Pset_
COBie	Other	COBie
NBS_General	General	NBS_General
NBS_Data	Data	NBS_Data
All objects developed or provided for the project will be stored inside the Object library in the CDE. Each object should comply NBS specification parameters as to be exported in IFC and COBie format. Thus, once the parameter are exported they are all stored in the right palace to guarantee the interoperability.		
NBS specification already contains Operational and Maintenance parameters. The Facility Manager could agree on those parameters or add more of them according to project needs.		

5.2.7. Level of Development

This section is repeated from the EIR: in that document the specified LODs were generically addressed to disciplines. In the BEP, instead, each element has an assigned LOD according to the need. The table is structured listing the project's stages in the columns and the elements grouped by discipline in the rows. After the validation process, a LOD specific to each stage was not assigned. Instead, each element is evaluated for the information needed in the process in that stage (Table 26). The suggested LODs in the table serve only as an example. The BIM Manager is responsible for assigning an LOD to each element, being the person who better knows what is required to reach the final goal. According to the EIR, here we chose to use the BIMForum LOD classification, an explicative legend of which is provided. BIMForum classification use only one parameter to join the graphical (LOG) and no-graphical

(LOIN) information. If this differentiation would be put in place during the project development, another LOD classification should be taken into account. The following table contains only a part of the listed element; it is possible to find the full table in Appendix 2.

Table 26 – BEP Level of Development

Level of Development

Architectural Model

Model Element	Concept Design	Spatial Coordination	Modelling and Coordination	Automatic Licensing	Detail	Design for Construction
SPATIAL						
Site boundaries, setbacks	100	100	200	200	200	200
Grids	100	100	200	200	200	200
Levels	100	100	200	200	200	200
Zones	100	100	300	300	300	300
Spaces, rooms	100	100	300	300	300	300
SITE						
Topography	100	100	200	200	300	300
Excavation			200	300	350	400
Stormwater			200	200	300	400
Services	100	100	200	200	300	400
Roads	100	100	100	100	200	300
Parking	100	100	100	100	200	300

Structural Model

Model Element	Concept Design	Spatial Coordination	Modelling and Coordination	Automatic Licensing	Detail	Design for Construction
SUBSTRUCTURE						
Footings		100	200	200	300	350
Retaining walls		100	200	200	300	350
Subsoil drainage		100	200	200	300	350
STRUCTURE						
Floor structures			200	200	300	350
Beams			200	200	300	350
Shaft openings			200	200	300	350
Stair & ramp structures			200	200	300	350
Walls – load bearing			200	200	300	350
Columns			200	200	300	350

MEP Model

Model Element	Concept Design	Spatial Coordination	Modelling and Coordination	Automatic Licensing	Detail	Design for Construction
MECHANICAL						
Plant external			100	100	300	400
Plant internal			100	100	300	400
Services in risers		100	100	100	300	400
Louvers			100	100	300	400
Ductwork			100	100	300	400
Registers			100	100	300	400
Pipework			100	100	300	400
Controls			100	100	300	400

5.2.8. Project Milestones

In the last section of the document, the Project Milestones are listed according to stages (columns) and dates (rows) (Table 27). In the following table, each Milestone is subdivided into two sections: Deliverables and Meeting. The first section contains the list of the requested deliverable, while the second one contains the roles of the people who will participate in the scheduled meeting. Every stage may have more than one Milestone, according to the project's needs and the BIM Manager's decisions. It is possible to add Milestone by adding columns in the table. The following table only shows a portion of Milestone section as an example.

Table 27 – BEP Milestones

Project Milestones				
STAGE	**Milestone**	**Date**	**Deliverables**	**Meeting Attendants**
Concept Design	**Milestone 1**	**24/07/2020**	Concept Model	Client BIM Manager Architect
Spatial Coordination	**Milestone 2**	**30/08/2020**	Architectural Model	BIM Manager Architect Structural Engineer MEP Engineer Facility Manager
Modelling and Coordination	**Milestone 3**	**15/09/2020**	Architectural Model Structural Model MEP Model Federated Model	BIM Manager BIM Coordinator Architects Architect BIM Coordinator Structural Eng Structural Engineer BIM Coordinator MEP Eng MEP Engineer
	Milestone n	**30/09/2020**	Architectural Model Structural Model MEP Model Federated Model Drawings	BIM Manager BIM Coordinator Architects Architect BIM Coordinator Structural Eng Structural Engineer BIM Coordinator MEP Eng MEP Engineer
Licensing	**Milestone n + 1**	**15/10/2020**	Federated Model for Submission Drawings	BIM Manager BIM Coordinator Architects BIM Coordinator Structural Eng BIM Coordinator MEP Eng

Project Milestones

STAGE	Milestone	Date	Deliverables	Meeting Attendants
Detail	**Milestone n + 2**	**30/10/2020**	Architectural Model Structural Model MEP Model Federated Model for Construction Drawings Schedules Quantities Details Costs	BIM Manager BIM Coordinator Architects Architect BIM Coordinator Structural Eng Structural Engineer BIM Coordinator MEP Eng MEP Engineer
Design for Construction	**Milestone n + 3**	**15/11/2020**	Architectural Model Structural Model MEP Model Federated Model for Construction Drawings Schedules Quantities Details Costs	BIM Manager BIM Coordinator Architects BIM Coordinator Structural Eng BIM Coordinator MEP Eng Contractor Sub-Contractos Facility Manager
	Milestone n + 4	**30/11/2020**	Architectural Model Structural Model MEP Model Federated Model for Construction Drawings Schedules Quantities Details Costs	BIM Manager BIM Coordinator Architects BIM Coordinator Structural Eng BIM Coordinator MEP Eng Contractor Sub-Contractos Facility Manager

6. COMMON DATA ENVIRONMENT

The Common Data Environment (CDE) is a single source of information for the BIM process used by multidisciplinary teams to collect, manage and exchange all the project's information and documentation. It is a system designed to manage data, include documentation, graphical model and non-graphical assets (Figure 30), enable the members of the teams to communication and avoid errors and duplications throughout the information lifecycle (British Standards Institution, 2013).

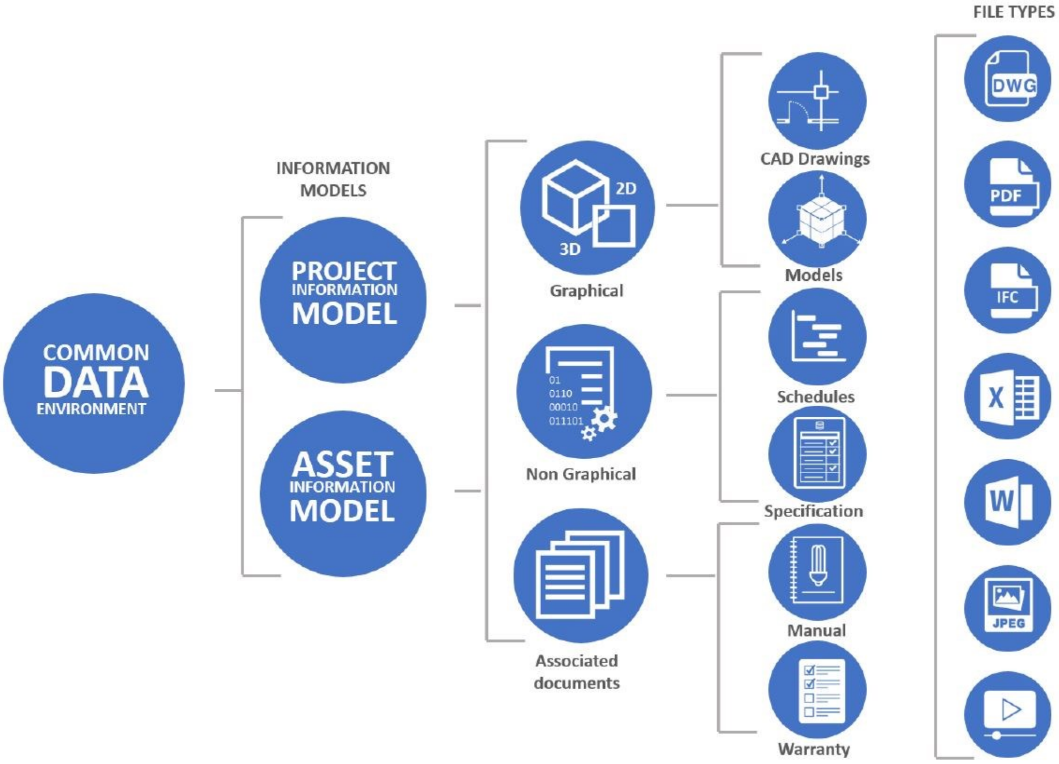


Figure 30 – Common data environment types and content summary (Mordue, 2018)

6.1. Literature Review

Collaboration between the stakeholders involved in the design and construction projects as well as in the asset management is decisive to an efficient delivery and operation of facilities. Besides, this may allow to achieve higher standards of quality and a better reuse of existing knowledge and experience for future projects. The CIC developed a supplementary legal agreement between professionals to support these services: the BIM Protocol. According to this, the Client should appoint an Information Manager to set up and manage the CDE; this person shall not be responsible for any design-related duty, but only for keeping information synchronised and coherent inside the environment and for assuring data security (MC Partland, 2016). The principles of the CDE should be well defined and described to meet the project's specification, the requirements and rules pre-established inside the EIR, and also to ensure that teams be working on the last available version of the file. Since the idea behind the platform is that it may function as a bridge that allows stakeholders to manage the whole lifecycle of the project, it needs to be well structured and organised, particular attention being payed to the security of data. With platform implementation, the CDE structure may be customised according to project's or companies' needs, but a core, standardised structure is still advisable. The BS 1192:2007 introduced CDE and its architecture; nowadays PAS 1192-2:2013 maintains this structure, having added the Operational phase to the process and the requirement to deliver non-graphical data inside the model. Also ISO 19650, according to the PAS 1192 series, demanded the use of the CDE to collect and manage information among the stakeholders throughout the project entire lifecycle.

PAS 1192 identifies four main folders for the CDE core, one per each stage of the work. The first folder being 'Work In Progress' (WIP); once the information is ready to be used by another team, it is passed on to the 'Shared' folder, to then be 'Published' and finally 'Archived'. The following Figure 31, acquired by BSI (2014) and modified by the author with comments, illustrate the information path inside the CDE. Information starts being collected by a PIM or an existing AIM or by external inputs, then it is elaborated by teams inside the WIP folder. Once this information is approved, it passes into the Shared folder to be approved by the client and, if validated, authorised and approved, it will be published and then archived. Each CDE folder holds different access and permission, so as to guarantee security. To this end, it is fundamental that the roles and responsibilities are well clarified from the very early stages of the process. Before moving data from one folder to another, this should be agreed upon and approved. Each folder should have a unique ID, following the agreed-upon naming convention. In order to avert inconsistencies, information deficit or repetition, it is also crucial that each team member put his best effort into respecting the naming conventions and the CDE structure: this will bring benefit to all the task teams and ultimately the entire project.

6.1.1. CDE Structure according to PAS 1192

- **Work in Progress** (WIP): contains unapproved information provided by each organisation or team for in-house use only. A supplementary section may be used to hold additional information for contractors;
- **Shared** (comprehensive of client shared area): contains checked, reviewed, and approved information ready to be used by other task teams, organisations, and stakeholders as a reference for the design. Once the information is checked, it is placed in the client area, awaiting approval from the Client or their representative (BIM Manager)
- **Published**: the information has been approved or accepted by the Client, and it is ready to be used for authority submission, tender or construction;
- **Archived**: this is the last step of the information lifecycle. This folder is used to store information and record of the projects for future uses.

The project input could be a PIM, an AIM, or a direct input depending on the case. Inside the CDE information and data are handle in the same way.

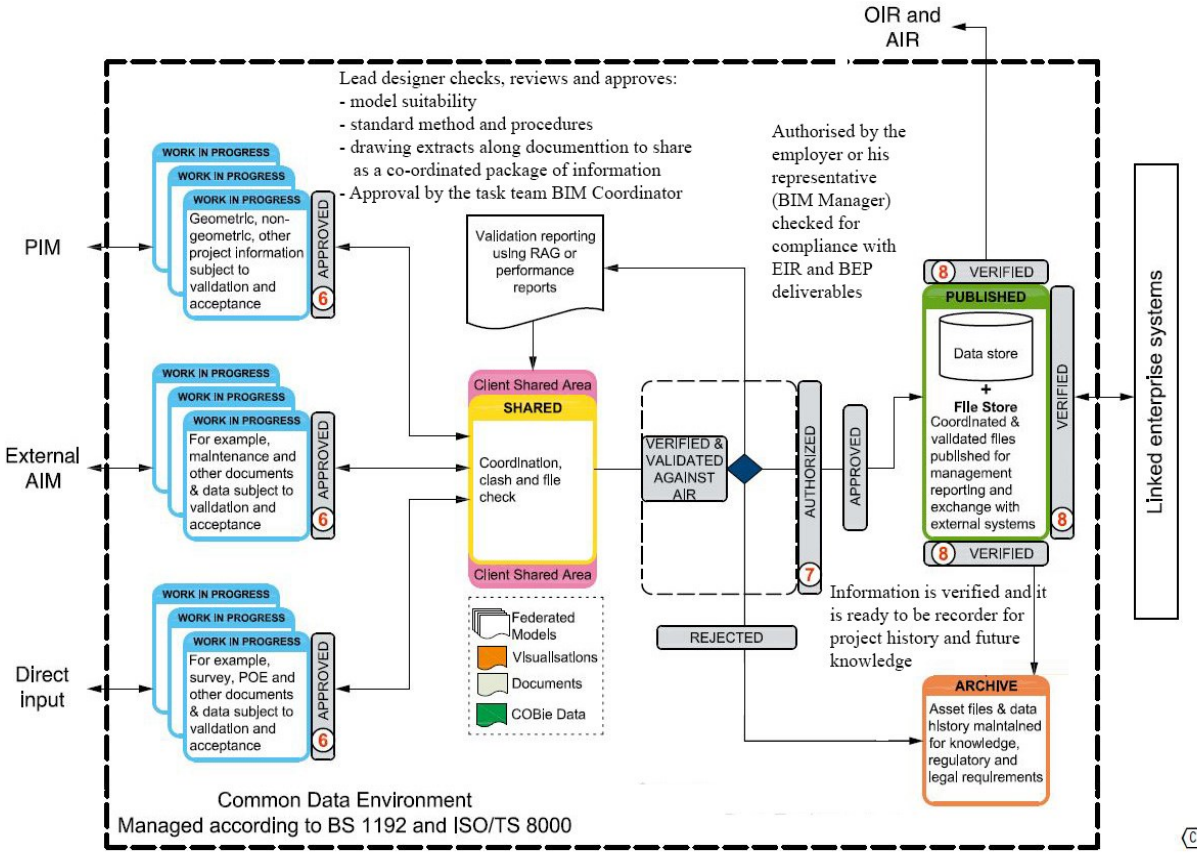


Figure 31 – Process map within the CDE - adapted from (British Standards Institution, 2014)

As BIM covers the entire lifecycle of a project from strategy to demolition the PAS 1192-2:2013 regulation identifies two main phases: the Development phase (CAPEX) – for strategy, design and construction (PAS 1192-2) – and the Execution phase (OPEX) – for management, maintenance, restoration, requalification and demolition (PAS 1192-3). This will introduce the topic of a 'non-new' project, which is to say of a project functional on existing buildings. In this case, the starting point of the project will have to be an Asset Information Model after an assessment evaluation of the building. In the regulation, this point still needs to be improved, as there is an overlap between PAS 1192-2 and PAS 1192-3 (to be developed) in the transfer of handover information from the PIM to the AIM. The extraction of legacy information forms part of the employers information requirements for re-build and refurbishment project' (British Standards Institution, 2013), as it is noticeable in the following Figure 32.

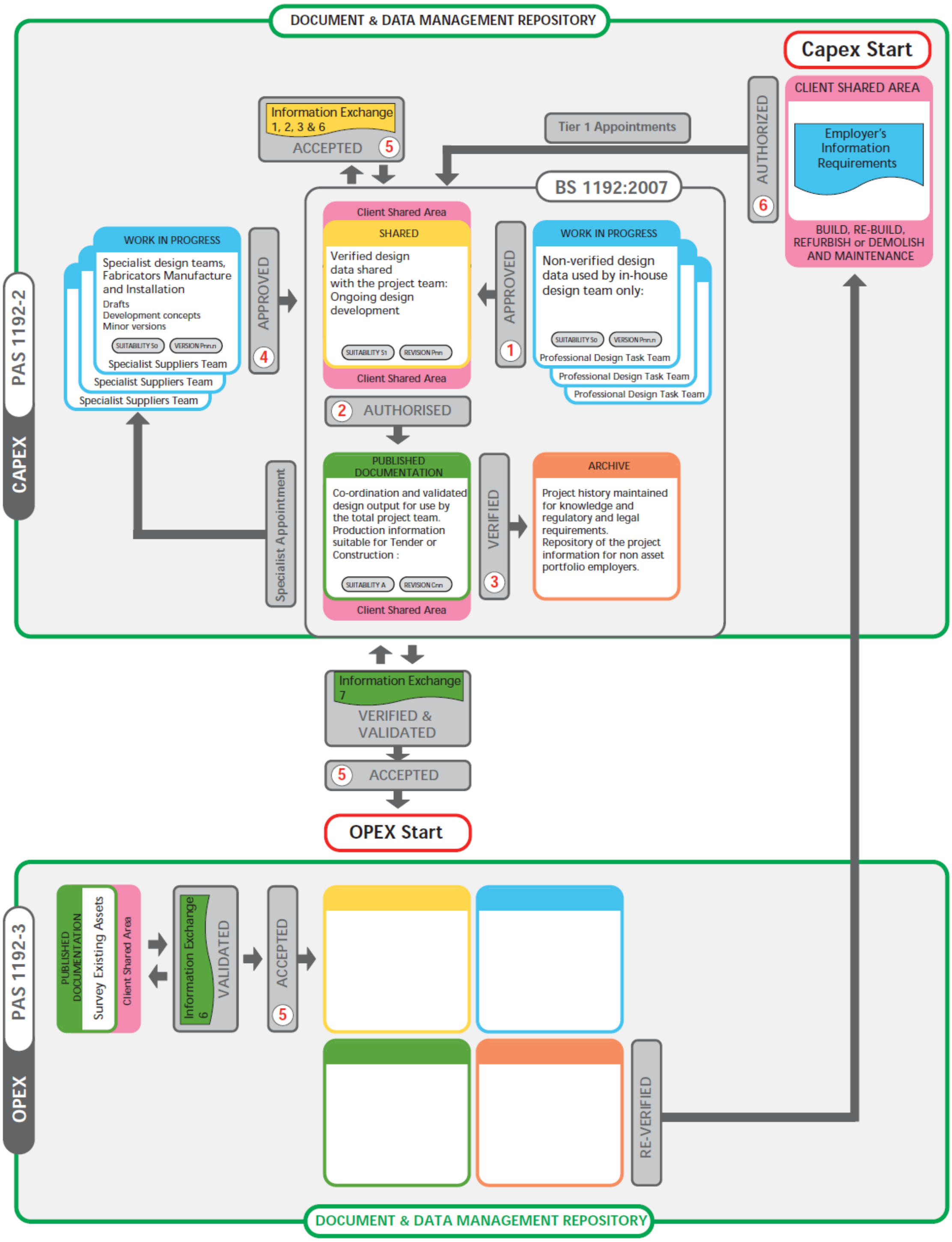


Figure 32 – Process map within the CDE (British Standards Institution, 2013)

Granted that the information contained in the Common Data Environment is shared and stored in a common platform (that could be cloud-based or not), who is the owner of that information? This problem can be avoided by purposefully restricting access to that information. The information originator is its owner, even after it has been shared. As regards models stored in the WIP, they have their own authorship and are shared with the other teams only in the standard, pre-agreed IFC format to be joined into a federated model. One issue regarding the ownership of objects could still be in place during the Design for Construction stage, while they pass from the design team (that owns the intellectual property) to the Contractor (the one who will adapt the object/model for construction purpose) (MC Partland, 2016). This is still a grey area, and in this respect very precise specifications needs to be added in the contract. Generally, it is the Client/Owner who requires the use of a specific CDE platform, for which they will get a license in order to be able to use the information stored inside and extract it for purposes related to the project. A sub-license from the Client is also granted for the team members who need to use other teams' models in the common exchange file format, IFC, to extract the needed information and enable the necessary collaborative work.

6.1.2. CDE use advantages

Design and construction phase:

- Improves information management;
- Improves communication and coordination between teams reducing time consumption using shared data;
- Assures information security between folders and groups members, preserving the information ownership of the originator, who is the only one able to change it using the original authored tool;
- Supports document/model view generation to compare different asset solution using the last asset version;
- Supports analysis and model optimisation;
- Supports models visual checks;
- Facilitates the process to gather information;
- Reduces the risk of information duplication;
- Assures the use of the last version of the models/documents/information;
- Assures data reliability and tracks the information flow through data revisions and versioning;
- Supports unlimited document production through different model combination;
- As an online platform, storage could be improved according to needs.

Operational phase:

- Guarantees access to reliable and relevant information;
- Assures a safe information transfer among the project's phases;
- Permits information storage and information retrieval;
- Improves spatial coordination using a federated model;
- Enables managing processes and maintenance planning for the future use of the building;
- Improves the built asset strategy;
- Allows the reuse of stored information for future projects improvement.

With the increase of IT involvement in BIM software and tools, many software companies started to develop their own CDE platform. This resulted in a new platform being released every year. All these CDE programmes are created with the purpose of assuring team cooperation and a continuous flow of information using the common industry file formats (IFC) or a native authored file format (this is the case for Autodesk, Graphisoft, Bentley, etc.). Unfortunately, many of these software do not allow open communication between formats of different developers. This issue can be solved, even if not completely, using the IFC format to assembly the federated model. Most of the CDE allow the user to explore the federated model inside the platform without downloading it; some of them also permit mark-ups and reporting. Despite the use of the IFC format and the COBie schema, though, it still proves to be difficult to pass information from one authored platforms to another without downloading it to a local server. As already mentioned above, the CDE is chosen by the Client, who buys the license. For this reason, every project that a single company may embark on may have a different CDE platform. Therefore, the BIM Manager, the Information Manager, and all the teams' members need specific training at the beginning of each project to achieve the higher possible level of information consistency and exchange in the CDE. These platforms' licences are generally expensive and for projects with a low budget it is not convenient to buy one. In these cases, the CDE could be put together using common shared folders inside a server or a free cloud-based application (e.g. Google Drive, Dropbox or others). The crucial points of the CDE, even in small projects, remains the same still: model and information ownership, folders access, and accurate naming convention protocol.

6.1.3. Criteria of a comparison analysis matrix for CDE

Due to the increasing amount of CDE platforms available, creating a matrix to analyse their features and capabilities may be a useful deed. The main areas to be assessed and compared before choosing a CDE platform are: access capability, data security, information management, information exchange, information storage, and reusability.

Important CDE platforms' features for evaluation:

- **User-friendly Interface**: an intuitive use of the platform simplifies information storage, thanks to a better comprehension of the environment and structure. A different interface/environment to manage drawings and documents could help differentiate, inside the same platform, the design-construction phase and the maintaining and operational phase, as well as the information management phase.
- **Secured login and access privileges**: it should be possible to set permissions to log into the server and give access to the folders according to the project's role, as per RACI matrix agreed in the BEP.
- **Controlled access to the BIM-server**: in every building, during the project's lifecycle, roles could increase and overlap compared with the ones planned at the beginning. To facilitate this process, it is essential to provide features that allow to add permissions and access rights to the server.
- **Hierarchical customisable structure**: each CDE is designed using a hierarchical model, but clients or companies might want to be able to customise this structure according to their requirements.
- **Nomenclature editor**: the platform should be provided with the option to change the nomenclature system during the process whenever needed, and to maintain edit rights.
- **Data management and notification**: during the modelling and coordination phase, some issues may rise while the single disciplines models are merged in the federated model. To maintain a high-level of coordination, the CDE software should send a notification to its members every

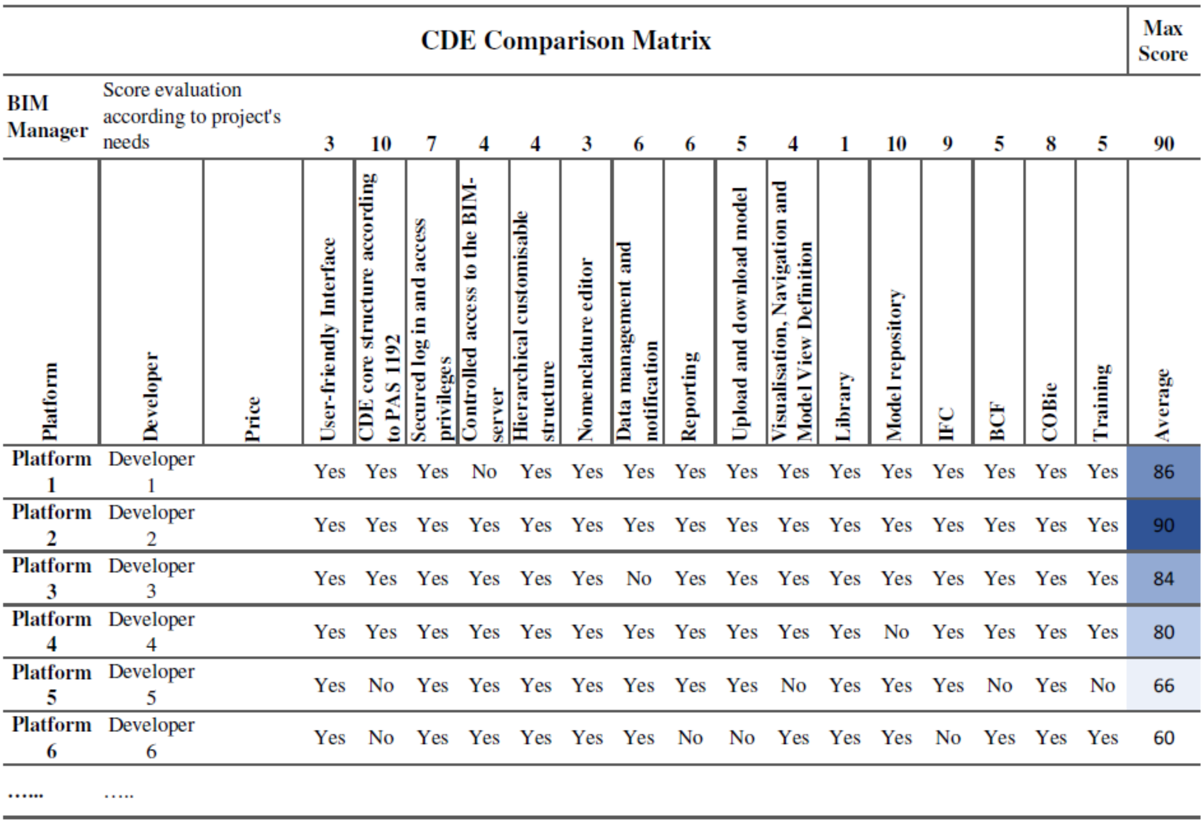
time a new file is uploaded. It should also create a downloadable backup folder to keep track of past versions of the model, thus avoiding the possibility to lose the entire work due to a malfunctioning.

- **Reporting**: it is important to be able to address, inside the platform, the model/drawing and documentation issues to each team.
- **Upload and download model**: upload and download task team models in the IFC format, so as to link them to the user model for better coordination.
- **Visualisation, Navigation and Model View Definition**: it is important to support the Design Stage and the revisions to filter information according to needs.
- **Library**: it should be available the possibility to store objects in a shared folder, to be used in the project or stored for future needs.
- **Model repository**: the platform should have a repository where to store and retrieve information for future use. Or better yet, should allow for the possibility to link that repository folder to others, may these be from the same developer or not.
- **Interoperability**: it should use common formats to exchange information (IFC, BCF, COBie), so as to have information consistency.
- **Training**: the provider should supply training for the platform and inside the CDE there should be a dedicated area for FAQ and small video tutorials to support users to a correct use of the platform.

6.2. Developed CDE Matrix comparison analysis

According to these criteria, a matrix was developed to help a company to support its Client in the choice of the CDE (Table 28). It could also prove itself useful for internal analysis on a BIM Implementation process. The matrix implementation was based on research and literature review. Regardless of the entity of the project, the CDE should respect the core structure suggested by PAS 1192, i.e. contain the main four folders: WIP, Shared, Published and Archived. This requirement will also be utilised as an evaluation criterion. If it is true that the CDE customisation of the platform is important, a fixed core structure is paramount to maintain coherence and accuracy in the process. One of the customisation criteria will also be the possibility to amend the platform – as explained in PAS 1192-3:2014 – to make it work whether the starting point is an existing building or a building yet to be constructed. The CDE will thusly need to begin containing an AIM that will become a PIM and then an AIM once more, at the end of the process. The latter model will so be stored in the platform at the end of the project's lifecycle. This matrix was structured by listing the platforms to evaluate in the rows and the evaluation criteria in the columns. The only exception is the first row, dedicated to the BIM Manager. Being the one who better understand the requirements needed by the client, the other stakeholders, and the project, they will be able to set priorities for the criteria. In order to do that, they can give a score weight evaluation to each criterion (0-10), to be assigned according to the project and the teams' needs. Criteria could be added according to different needs. The last column shows the average assessment according to the BIM Manager scores and the platforms' features. In case of a tie in the evaluation between platforms, the BIM Manager may make his decision basing on the 'Price' column. The criteria used for the evaluation are the ones listed and explained in the previous sub-chapter (6.1.3). Instead, the attribution of 'Yes' or 'No' platform evaluation is only used as an example. A gradient of colour was used to quickly identify the platform which better accomplishes the project’s needs according to the BIM Manager evaluation. White cells correspond to the lowest grade, while dark blue ones to the highest.

Table 28 – Developed CDE Matrix comparison analysis



CDE Comparison Matrix																			Max Score
BIM Manager	Score evaluation according to project's needs		3	10	7	4	4	3	6	6	5	4	1	10	9	5	8	5	90
Platform	**Developer**	**Price**	**User-friendly Interface**	**CDE core structure according to PAS 1192**	**Secured log in and access privileges**	**Controlled access to the BIM-server**	**Hierarchical customisable structure**	**Nomenclature editor**	**Data management and notification**	**Reporting**	**Upload and download model**	**Visualisation, Navigation and Model View Definition**	**Library**	**Model repository**	**IFC**	**BCF**	**COBie**	**Training**	**Average**
Platform 1	Developer 1		Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	86
Platform 2	Developer 2		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	90
Platform 3	Developer 3		Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	84
Platform 4	Developer 4		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	80
Platform 5	Developer 5		Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	66
Platform 6	Developer 6		Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	60
……	…..																		

In Table 29 it is possible to find listed some CDE platforms available in the market.

Table 29 – Example of CDE platforms available in the market

Platform	Provider	Website
A360	Autodesk	https://a360.autodesk.com/
3D Repo	3D Repo	https://3drepo.com/
AEC Hub	AEC Hub	https://aechub.io/
Asite	Asite	https://www.asite.com/
BIMCloud	Graphisoft	https://graphisoft.com/solutions/products/bimcloud
BIMcollab Cloud	BIMcollab	https://www.bimcollab.com/en
Bimsync Arena	Bimsync	https://bimsync.com/
BIMXtra	Clearbox	https://www.clearboxbim.com/products/bimxtra
EcoDomus	Ecodomus	https://www.ecodomus.com/
Groupbc	BC Group (Bentley)	https://www.groupbc.com/
Oracle	Aconex	https://www.oracle.com/it/industries
ProjectWise 365	Bentley	https://www.bentley.com/it/products
Revizto	Revizto	https://revizto.com/en/
Trimble Connect	Trimble	https://connect.trimble.com/
Viewpoint	Viewpoint	https://www.viewpoint.com/

7. VALIDATION AND OUTPUT OF THE DEVELOPED WORK

This chapter addresses the validation of the developed workflow, already explained in Chapter 3, and the related developed documents to support it, explained in subsequent Chapters. The dissertation work was supported and suggested by an international BIM consulting company *BIMMS – BIM Management Solutions* and designed to satisfy the need to create protocols and procedures that may allow information exchange among the processes of a project during the Design Stage. The dissertation outputs were validated in three different moments along with the work. The first one happened after the first month of work once the dissertation objectives were established, where a meeting was arranged to introduce the case study and to collect information from the company. Due to confidentiality issues, it was not possible to examine project documents and publish detailed information about the case study. The second moment of validation was in the form of a structured interview to one of the key partners related with the BIMMS production processes. The methodology relied on a question list regarding topics and BIM issues that was prepared and presented to the referent to be commented and to promote a brainstorm discussion afterwards. At the end of the dissertation work, once a few changes were made on the developed documents for their implementation, the final validation moment occurs and consisted on a presentation of the complete work to a panel composed by BIMMS selected professionals.

7.1. Case study presentation

The first meeting was organised with two of the partners of the company and the two BIM Coordinators of the case study. This moment had the format of an interview and was focused on the case study presentation, technical and software related issues and strictly project-related questions. A list of questions was prepared on BIM processes of the Design Stage and information requirements collection to conduct this first meeting. The case study concerns an educational complex currently in the construction stage The project started six years ago (2014), and it was considered a front view project by the government, which demanded the use of BIM with particular focus on how the BIM process will be handled following the highest standards at the time. The education Institution was trying to secure a construction company with design capabilities, to help advance the design from stage two (Concept Design) to stage four (Technical Design) – according to RIBA Plan of Work – while moving on with the construction. One of the main problems of this project regards the Design Stage, as the initial project's design was completely changed during the construction phase, as the designers were not related to the construction company, and each time the construction company had to make changes on the project, they needed to wait for the designers' approval. BIMMS was involved by the Contractor mainly to support the design stage that was not adequate until the Contractor started to work to the project. The company was responsible for verifying the design compliance, coordination, and the quality assurance of the MEP systems according to the RIBA Plan of Work stages. They needed to track the information required and verify whether they were compliant and, if the information was missing, retrieve it and insert it in the correct flow.

The owner of the project is the educational institution, but BIMMS's client was the construction company which was also the main Contractor. BIMMS was involved in the project only at an advanced stage. For this project, a Design-Build contract was stipulated: the client was responsible for creating the design and then build it. The design manager indicated the needs and the requirement for each different stakeholder, phase by phase, in a separate document to be given to each team. Roles and responsibilities, LOD, information, and detail all were established according to the RIBA Plan of Work. The employer in the contract was requesting an average final level of model development. Deliverables were defined in the contract from the start; every additional deliverable requested was added to the Task Information Delivery Plan (TIDP).

By contract, it was established that work for the Design Stage had to be developed using Revit 2016 for all the models and the Federated model had to be created using Navisworks. A common platform (Asite) was furthermore established, as a place where all the deliverables needed to be published (models, drawings, schedules, documents, lists, specifications, etc.) for the design and building team. A second platform (Conject) was established for the communication between Client, Contractor and Project Manager, who validates the documentation according to the client requests. The Contractor's team was responsible for uploading the documentation to be approved in the second platform. All the stakeholders were able to use BIM technology, albeit with different levels of maturity and capabilities. Sometimes few stakeholders were not confident with BIM terminology or its practical use. Whenever this lack of knowledge caused issues, they were solved without significant conflicts and with minor time loss. In the beginning, a BEP with the client requirements was established during the design process and then changed several times, to be adapted to changing needs. The latest version of the document was uploaded two years ago.

According to the BIM Coordinator, the document was well structured and defined. Despite this, during the interview, one of its most emphasised issues was the software versioning. Due to this important project's long incubation period, the previously established version of the design authoring tool (Revit 2016) is not available on the market anymore, and the software house is not distributing revisions either. The problem was raised by new stakeholders involved in the project: according to the contract, they ought to have procured the 2016 version, despite it not being available anymore. The workflow was, therefore changed in order to meet the needs of everyone involved.

Despite some improvements in management, the overall Information Management process still contains endemic issues. Since the subcontractor is in charge of the MEP systems, the main Contractor is responsible for the MEP models and their properties. In order to make changes to the design of the building, due to technical and MEP related problems, the subcontractor and the Contractor need to have the designer's approval. Each team and each stakeholder need to have their own quality control process for the model. If issues between models appear, the responsible is reported after each stage control and clash detection process. The following image (Figure 33) represents the required standard for clash detection tolerance between different discipline models:

Clash Test	Tolerance
Architecture vs. Services	
1.01 Architectural Ceilings vs. Services	0.025m
1.02 Architectural Doors vs. Services	0.025m
1.03 Architectural Floors vs. Services	0.025m
1.04 Architectural Interior Glazing vs. Services	0.025m
1.05 Architectural Linings vs. Services	0.025m
1.06 Architectural Partitions vs. Services	0.025m
1.07 Architectural Stairs, Steps and Railings vs. Services	0.025m
1.08 Architectural Walls vs. Services	0.025m
1.09 Architectural Walls vs Facade	0.025m
Structure vs. Architecture	
2.01 Structural Beams vs. Architecture	0.025m
2.02 Structural Columns vs. Architecture	0.025m
2.03 Structural Concrete Upstands vs. Architecture	0.025m
2.04 Structural Floors vs. Architecture	0.025m
2.05 Structural Piles vs. Architecture	0.025m
2.06 Structural Framing vs. Architecture	0.025m
2.07 Structural Walls vs. Architecture	0.025m
Services vs. Structure	
3.01 Cable Trays vs. Structure	0.025m
3.02 Ducts vs. Structure	0.025m
3.03 Electrical Equipment vs. Structure	0.025m
3.04 Mechanical Equipment vs. Structure	0.025m
3.06 Pipes vs. Structure	0.025m
3.07 Risers vs. Structure	0.025m
Facade	
5.01 Facade vs. Services	0.025m
5.02 Facade vs. Structure	0.025m
Civils	
Civil Drainage vs. Structure	0.025m
Civil Drainage vs. Architecture	0.025m
Subcontractor Packages?	

Figure 33 –Case study clash detection test tolerance and disciplines

Once the coordination is validated, the drawings are uploaded to the CDE platform to be approved by the Project Manager. According to the validation, so as not to stop the process, it is possible to start working on site on the approved part of the work.

The main issue underlined by the MEP project coordinator was the lack of accuracy and timing in the as-built model delivery: this caused many delays in site and problems during work coordination. The model delivery ought to be better defined at the beginning of the project.

7.2. Structured interview to BIMMS technical coordinator

A second meeting was conducted with Eng. Bruno Caires, technical coordinator and partner of the aforementioned firm BIMMS regarding BIM processes, information management, and practical knowledge of the problems of BIM technology. It was a deep interview that was recorded, with the agreement of the interviewee, and later analysed.

The workflow, procedures, and documents were validated using the qualitative research method of in-depth interview developed by Yale University (Yale University, 2015). The purpose of using an in-depth interview is to better explore individual experiences and perceptions. During the meetings, general observations about BIM development, procedures, and tools were made comparing knowledge from the author's experience to the respondent's expertise. At the end of those meetings workflow, documents, and developed matrixes were refined and inserted in the paper. According to the chosen research method, several interviews were conducted with two people with a different level of involvement inside the company and the case study.

The interview was conducted using a structured list of questions, designed to engage the respondent and guide him to the developed processes validation and, additionally, as a basis for the conversation (Yale University, 2015), where additional questions were made in the discussion flow. The interview and inquiries were made with the collaboration of Fontana, due to the shared topic and complementary work. The question list of the interview with the partner of the company are presented in Appendix 3.

As regards the Design Stage, having explained the stage subdivisions of the developed workflow, were approved the identified five stages subdivision (Concept Design, Spatial Coordination, Modelling and Coordination, Automatic Licensing, Detail, Design for Construction). Discipline models' evolution across stages was also validated as well as per the Federated model progression. Going deeper inside the stages and analysing the stakeholders' role inside the steps, the workflow was validated by agreeing on procedures, deliverables and phases succession. The Design management, instead, according to Caires, could be handled differently, over the personal BIM Manager view and practice: ‘some Managers prefer a more contractual approach, without getting involved in the technical aspect, others the opposite. This 'hands-on' approach gives the Manager a more in-depth knowledge of issues, a ‘connector’ of sorts between different disciplines, facilitating the communication across stakeholders and enable problem-solving. According to the interviewee, it is good practice to set a workshop among the stakeholders every one or two weeks (depending on the stage), to solve any issue and keep track of the project progress. Those macro-meetings workshops across disciplines are not enough to control projects, though; a day-to-day communication schedule has also to be settled. This can be merely share-file based, i.e. supported by micro-meetings to rise any critical issue or miscommunication and to find solutions. Specific platforms, such as BIM Collab, may be up to this task, with the only problem being the licensing. It is, however, possible to avoid this issue by using free sharing live update tools such as Google Documents, Microsoft OneNote or others. This speech validates and improves the EIR and BEP templates in their 'Collaboration and Issues Management' sections, suggesting to implement a daily communication procedure between the BIM Manager and the other stakeholders.

There were mentioned few advantages brought by the BIM to the AECO industry and that, nowadays, all disciplines and stakeholders are more closely related and interdependent than ever before. Every time a model and, consequently, a drawing is made, the person responsible has to take into account that other stakeholders will use it to build on their work. BIM also changed the contractual methods, asking that more requirements be settled at the beginning of the process, thus improving coordination and hastening problem-solving. All these issues could be solved by detailing the information management processes in the contract, trying to create the most efficient one. Choosing the right team becomes, therefore, a pivotal feat, as well as settling the correct timing for milestones and stages. This validates the choice of settling an open collaboration in the developed workflow since the stage of 'Preparation and Brief' and maintaining it until the last stage of 'Detailing for Construction'.

The list of questions for the interview was structured in topic blocks to reflect the developed workflow analysis. Before forming teams and settle requirements, it is necessary to establish the contract. In the interview, the three typologies of AEC industry's contracts were examined: Design-Bid-Build, the Design-Build and the Integrated Project Delivery. The conversation focused on analysing those documents differences on the basis of Caires' experience. ‘Nowadays in BIM processes the most popular form of contract is the Design-Build contract, as it is the best one to experience the BIM benefits’; it permits, in fact, the concurrence of design and construction processes, facilitating a fast-track approach between the two disciplines. In this type of contract, BIM enables a more consciousness decision-making process based on a reliable and transparent comparison between several possible scenarios. ‘This methodology, however, has the flaw of not including the Facility Manager and thence the Operational phase in the process’. The Design-Bid-Build, as a traditional contract methodology, is instead a fragmented process with a sharp contrast between the approaches and focuses of the designers and the contractors. ‘Moreover, the Bid process is time-consuming. It has also to be taken into account that every time the construction starts, some issue in the design could be found and it needs to be sand back to the designers to be solved, consuming more time. This type of finish-to-start process extends the time between Design Stage and construction, leading to subsequent delays, from a stage to another’. As regards the Integrated Project Delivery, if well implemented, *‘*it is considered the best contractual methodology*’*, since every stakeholder can benefit from it. Itwas suggested the possibility to integrate some of the best policies of the IPD to the Design-Build agreement in the meanwhile the IPD contract methodology will be improved. Despite the IPD methodology not being the most common contract in use and it still presenting difficulties in coordinating and defining its contractual limits, the workflow was developed thinking about this form of agreement. The choice was made addressing the best practice for the future development of BIM and aiming to gain the best results from it.

After choosing the contract, it is essential to think on how to evaluate and structure the project teams. Once the company has to hire new people for a project, it settles an adaptation period and schedules some training to ensure his employees have full knowledge of BIM methodology, so as to speed up processes taking care of the information exchange and storage. It was highlighted the importance of understanding the method and going through its process for being able to reproduce it and preparing the model to be interoperable with other interfaces. To assure the process enhancement and the employer capabilities, these capabilities should be assessed every each or, at lease, once a new project stars. The 'Project's team members maturity level assessment' matrix (2.2) was developed as to be used before and after the training to keep track of annual reached targets and also as a support for new employee recruitment. During the interview, the fact of having specific and certified competencies was raised as a crucial point, and therefore a specific column for certifications was added to the matrix.

Once a team is put together, it is important to gather information requirements. On the contract evaluation base in the developed workflow, the Facility Manager was involved in the project from the beginning to support the Client establishing the Asset Information Requirements (PAS and ISO Standards). This procedure is considered to be the most appropriate to obtain the maximum result for the project (IPD).

After the AIR are settled, the BIM Manager is entrusted with the task of helping the Client set out his own **r**equirements. During the interview it was also validated the role of the BIM Manager acting on the Client's behaviour and on having a clear overview of the project under many aspects. ‘Having the end of the process in mind and knowing the problems that could raise in the project, he is the most qualified professionals to set up the requirements needed to achieve the demanded results’. Ideally, the BIM Manager should be supported by all the other stakeholders gathering their system requirements. This complies with the developed workflow for the Preparation and Brief stage. As the BIM development is growing, it should be advisable to start standardising the project, having a base document for the EIR as a guideline to customise project by project according to the needs. It is important for the company to develop its own Information requirements document to know which ones are generally the deliverables, the drawings to be extracted from the model. It was mentioned the importance of knowing which information are required to implement within the model, where are stored, and which one needs to be extracted to automatise the process. This is also compliant with the developed EIR (4.2). in fact, if well planned and properly settled, one of the most powerful resources of BIM is the use of the model as a reporting tool; it is possible to report several project's options to the client, to be compared and evaluated on a reliable and transparent information base.

The BIM Manager also has to gather system requirements from all the parties and produce the BEP (3.3). For what concerns the BEP, the interview aimed at validating some sections of the developed BEP (5.2). Questions were about LOD, interoperability and file format, data segregation, data security, intellectual property, and protocols for issues.

In the referent experience, the establishment of LOD should not be arbitrarily based on the phases, as it is in the academic world. Rather, it should be established according to the deliverables and the uses of the model opting for the minimum LOD required to achieve the same result. The reason to use the minimum LOD required to obtain the information needed from the user to make a decision is to save time in the modelling part, hence reducing costs. Following this, the developed BEP template doesn't have a standard LOD per phases. The aim, for the company, is to try and standardise those LOD for each element, trying to apply them to all future projects.

Starting from the case study's issue regarding the authoring software versioning, the topic of interoperability was explored as well. Versioning is an important matter, especially on long-period projects, for all the aforementioned reasons. The proposed solution in the developed work is to insert a requested version in the contract and in the BEP, to be updated every 2/3 years. 'This solution still presents some difficulties, as in big projects there are not just 4-5 models merged in a federated one, but rather 85-90'. Every time a version is updated, essential checks must be performed to assure the models' quality and that no information is lost in the process. Unfortunately, according to the interviewee opinion, and based on his experience, there is not yet a perfect solution to the problem, this major method problem is the time-consuming. Nevertheless, the offered solution is considered valid if the versioning migration is supported by the IT. Another critical issue related to this is the choice of the hardware: it is important to establish at the beginning which is the hardware requirement and to verify it, so as to save time and money.

The conversation then proceeded towards interoperability, specifically concerning the importance of the IFC schema used as the commonly format for interoperating among different software. It is necessary to know the software and the IFC schema to know where to place the requested information to later having it located in the correct position even under the other software. A possible solution to this problem might be that of hiring people that already possess this set of skill to work on the project (2.2). Another limitation of this format is the impossibility to make a change on the IFC file and send it back to the originating software. It would be useful and engaging to develop a code or platform to enable this function, achieving improved interoperability and independence from the authoring software. Still on interoperability, the interviewer addressed the issue of another open format, COBie, to see if the company was using it and to know the interviewee's opinion on its benefits. One of the positive features of COBie is the possibility of setting the parameters in the project or template and immediately having the work done in whole project. If COBie use is defined at the beginning, in the handover phase, it might save considerable time to the Client or the project management team: the software will in fact provide the folder structure of the building early in time and it will also be a support to the teams' work on project design. COBie, as an open format, will enable communication among software and stakeholders that do not deal directly with the model but need to extract or insert information from/to it using Dynamo or other similar software. This validates the use of IFC and COBie open formats to exchange information along the project lifecycle. The capability of CDE platform to support those formats was also used as an evaluation criterion for the platform itself.

Using IFC schema, it is furthermore possible to assemble the Federated model, composed of several discipline-related models. Each one of these disciplines models has to be adequately managed with data segregation procedure. It was mentioned the importance of the model workability, especially in big projects, to not decelerate the workflow. It is important to understand how to fragment the model; for the structures, a possible solution could be to break the model using movement joints, thermal expansions drains (where the building will be separated) or by level. As regards the architecture, instead, it is effective to understand how to split the work (model) inside the office; it could be divided between vertical (walls) and horizontal (floors) elements. The BIM Manager, once again, has the responsibility to make this decision, having the best practices and the outcome requested by the deliverables in mind. What is advisable, nowadays, is trying to change the mindset of the design, starting to think more to the relationship with the construction phase. The BIM Manager has to think about the models' fragmentation, bearing in mind the deliverables needed to proceed to build area by area. This procedure aims at closing the construction of a specific area and doing that in an integrated way, enabled by the collaboration of using BIM with the federated model, the CDE, the IPD, etc.'. This validates the data segregation sections in the developed template as it was purposely assigned to the BIM Manager for his consideration. The segregation method could be found in the EIR specifications (4.2).

When interoperability is settled, and the Federated model is set up, it is possible to exchange information between disciplines and stakeholders. In order to be able to exchange information transparently and reliably, it is important to establish protocols to report and deal with issues. In the case of clash detection, clashes could be reported to each team in different ways. It should be also considered that to each clash corresponds a drawing, a document and a deliverable. For this reason, it is advisable to map clashes and thusly check every document for drawing changes. Another good method is to use the model as a reporting format to enable everyone to check revisions and map changes per level, per room or other. The BIM Manager is the responsible for running clash detection; in the case of a big project, each BIM Coordinator will run a clash detection per each discipline, before uploading the model to the Shared folders in the CDE. It was highlighted how, in terms of design and construction site relationship, it is a good practice not to focus on all clashes at the same time, but rather on what is ready to build, creating a hierarchy of what to fix based on the areas to complete. The aforementioned practice aims at keeping the construction site functioning and, consequently, reducing costs. BIM use could easily support this procedure, helping with time and construction programming. The same operation could be practised on the model quality assurance. After the validation interview, those practices were inserted in the BEP template (5.2) to have an accurate document with the use of the best practices.

A crucial topic in the use of BIM, as discussed before (6.1.1), is data security and intellectual property. Those issues are generally managed in the contract before the project begins. For the security part, the company might be asked to provide a security certificate that certifies its reliability. As regards the intellectual property, as already mentioned, it should also be clearly defined in the contract, to avoid later issues and debates between Client and designers or designers and contractors. According to the contract agreements, there could be cases where the Client could repetitively use the information for different purposes, sanctioning their complete ownership over the information.

All the mentioned processes are managed inside the CDE as a unique source of information. In the case study, two CDEs were settled due to confidential, contractual, and commercial reasons. This issue could be easily managed with different permission accesses to the information. The decision of using only one CDE in the developed workflow was approved and validated. In the use of one CDE, it might be necessary to pay attention, during the drawing up of the contract, to who the owner of the licence is and how the accesses are going to be distributed.

It was mentioned the importance of not having the CDE ownership in the hand of only one person to avoid the loss of all the documents and drawing if the owner would close it for any reason. To solve this issue, it was suggested that the ownership of the CDE could be shared by three people. After the validation process – which considered this a more effective approach – this is the methodology which was proposed in the developed EIR. It was also agreed that the developed CDE evaluation matrix could help the Client and the BIM Manager to make wise and conscious project-related decisions on its selection. Once the Handover and Operational phase are carried out, the model passes from a Project Information model (PIM) to an Asset information model (AIM).

After the interview to evaluate and validate the workflow, the author made some improvements to the matrixes and the documents developed. The author's production for this dissertation work was presented in its final configuration, to avoid repetition inside the work itself. In the following Table 30 the improvement made on the developed documents are listed:

Table 30 – Documents improvements made after the validation interview

Documents improvement made after the validation interview			
Document	**Adopted comments**	**Non-adopted comments**	**Validation**
BIM Competencies Matrix			✓
Project's team members maturity level assessment			✓
Certified Competencies	Use certified competencies as an additional evaluation criterion		
Design Stage Workflow			✓
Contract		Use a Design-Build agreement – integrating some of the best policies of the IPD	

Documents improvement made after the validation interview			
Document	**Adopted comments**	**Non-adopted comments**	**Validation**
Sub-stages	Five sub-stages of designed were agreed		
Automatic Licensing	It will take time to be achieved, but it will happen in the future		
EIR template			✓
Collaboration and Issues Management	Daily communication procedure between the BIM Manager and the other stakeholders		
Software Versioning	Updated version every 2/3 years with the IT help to not lose information in the process		
CDE	CDE ownership should be shared between three people		
BEP template			✓
Collaboration and Issues Management	Daily communication procedure between the BIM Manager and the other stakeholders		
LOD	LOD per each element were defined according to information needed and not according to phases		
Developed CDE Matrix comparison analysis			✓

7.3. Final presentation to a professional company panel

Once produced documents and workflow were implemented and validated after the interview mentioned in the section above, a final meeting for the last validation was established. The final work presentation was prepared and presented to a panel composed of the three partners of BIMMS and the two project coordinators. The session started with the introduction of the dissertation objectives to continue with an in-depth presentation of the created workflow and a detailed explanation of its five supporting tools.

After the presentation, each member of the panel made questions on the work and comments on the developed tools. There were several last-minute suggestions that were still considered for this work, but globally the feedback was very positive and unanimously validating the importance of this work to the company. Some of the comments enhance a ‘great balanced work between academic and professional world providing tools for BIM implementation’. Furthermore the developed work, was considered a ‘strong organised framework’, a good work on the point of view of ‘management and strategic’ of the tools provided ‘touching the key items of how to prepare a BIM project’. Despite being appreciated the adaptability of the workflow and its related documents to BIMMS, this panel also emphasised its applicability to other companies which want to implement BIM as well.

7.4. Output of the dissertation

The dissertation had the purpose of creating a framework for BIM implementation inside a company for the Design Stage that also consider not only the practical aspects but also the strategic ones. Each chapter of this work contains one or more developed tools meant to support the developed workflow. The relationships between developed documents, tools and chapters' subject is schematically represented in the following Figure 34.

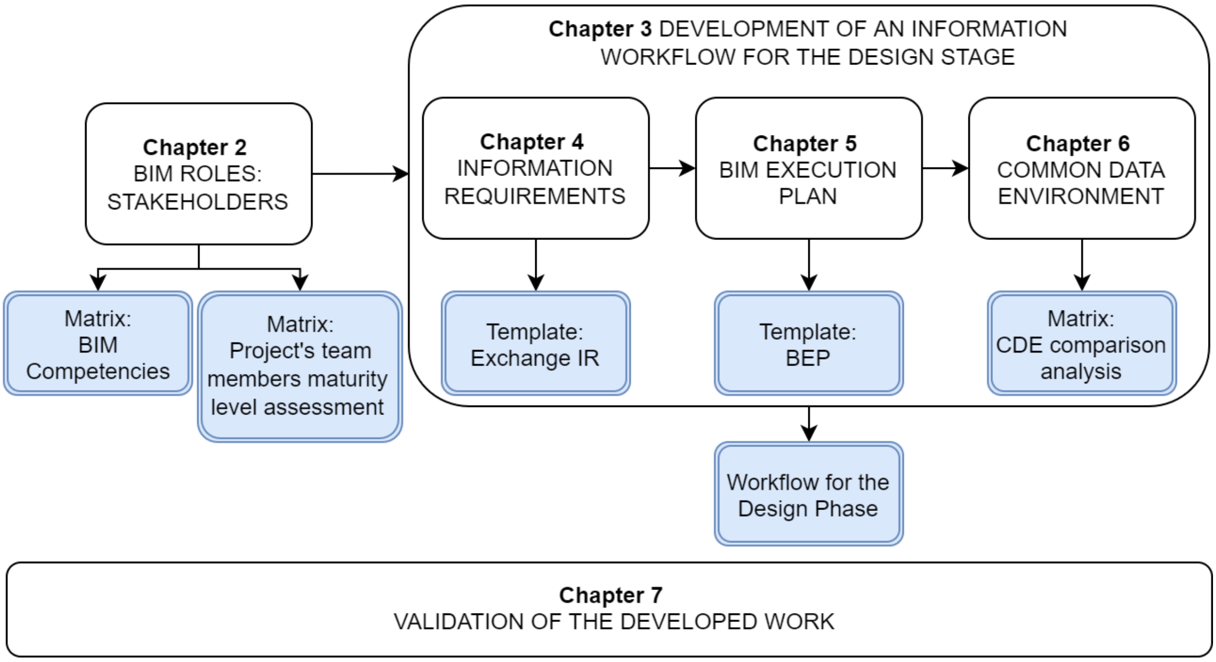


Figure 34 – Output of the dissertation

The adaptability of the developed tools and documents could also facilitate their use in different companies and in other countries with particular regulations. This work is not yet completely in the form of a manual for academic purposes but, through few shrewdness, it could be transformed into a handbook for companies which intend to implement BIM processes in the Design Stage.

8. CONCLUSIONS

Information Management in the project lifecycle is the central focus on BIM methodology. It is crucial to define the correct Workflow and processes to obtain from BIM adoption a desirable information exchange between stakeholders with open collaboration, design productivity, construction waste reduction, and a close connection since the first project phases with facility operations.

This research aimed to provide guidelines and tools to deal with the difficulties faced by any international consulting company on managing information of BIM-based projects. In particular was taken into account BIMMS which, as consultant company, asked a support for IM employment. This dissertation focused on the Design Stage and proposed several instruments aimed to support BIMMS on their information management during this stage. In-depth research made for each proposed topic was oriented to analyse the problem, identify the best practices and offer innovative solutions. The results were summarised and implemented in the created documents of the presented dissertation.

During this dissertation work, **six main outputs** were developed and provided for BIM implementation in companies. The created tools are listed and described below.

1. A **'BIM Competencies Matrix'** was developed, that clarifies the roles and their expectable competencies. The introduction of this tool will help the client and the BIM Manager to select the roles needed for the project and define their duties.
2. The related **interactive matrix of 'project's team members maturity level assessment'** intends to support the evaluation of team members on specific project-related competencies. This second matrix could also help the BIM Manager on choosing the most suitable candidate for a particular position, be useful to evaluate employees after a company training or to keep track of their personnel's progress.
3. The conceived **Workflow** strives to nurture open collaboration and clarifies stakeholders' actions and deliverables through the Design Stage. This 'process map' also intends to accelerate BIMMS project's processes once it is adopted.
4. To support the BIM Manager of the company to identify requested information requirements, an **Exchange IR template** was developed. The document adaptability assures its use in countries with different standards: its structure, in fact, it simple and easy to be filled in.
5. The simplified **BEP template** completes the requirements statement developed for this dissertation. Again, to assist the BIM Manager in his work, this document was created having in mind it could be tailored for different project types and locations.
6. Finally, to complete the work, the generated **'CDE Matrix comparison analysis'** aims to assist the company in advising the client in the CDE choice and for the company to develop internal analysis on BIM implementation process.

A good process implementation always starts defining the first steps to be moved in the correct direction. A better approach to BIM problems focused on leading the information management workflow will produce an efficient information delivery reducing waste of time and resources of the companies involved in the process. This dissertation work will serve as a simplified guide, gathering all the disperse information across the literature and proposing documents easy to be used. It could be useful and applicable to all the companies which will intend to implement BIM adoption. The presented guide for the BIM Information Management workflow on the Design Stage of Building Projects enriched by the created documents also answer to the BIMMS company problem in managing information along the design stage. Whether the company productivity and performance are improved, will depend on the application of these tools in future projects.

Future research could be conducted on investigating in an even deeper way each sub-stages of the proposed Workflow for further improvements on their BIM-based processes. It would also be considered, to enrich the IER template, to create the Organisational Information Requirements (OIR), Asset information Requirements (AIR) and Project Information Requirements (PIR) templates. For the same purpose, to enrich the BEP template could be developed a Master Information Delivery Plan (MIDP) and a Task Information Delivery Plan (TIDP) templates.

Further customisation and alignment with specific project types and locations of the developed tools can be explored. Since the company has projects in many countries, the applicable standard could be used to create tailored documents to count with specific versions for each country, resulting in an accelerated process by eliminating the document personalisation. It also can be taken into account a possible development on project key performance indicators and the creation of a matrix to track project progresses in time to make time previsions on next works.

The BIMMS board, during the final validation, also proposed two suggestion for future researches: a study on the handover between design and construction phase with the development of parameters to track the full coordination of the model and to extract quantities during the passage between the two stages; and a possible visualisation of the Project Milestones as a Gantt chart for a comprehensive understanding of milestones.

As the AECO industry is always evolving, there will always have need for future development, and this work is only a little step on BIMMS's BIM implementation but has the chance to be a substantial contribution to pave the way to structured information management for the company.

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LIST OF ACRONYMS AND ABBREVIATIONS

2D	2 Dimensions
3D	3 Dimensions
AECO	Engineering, Architecture, Construction and Operation
AECOOFM	Architect, Engineer, Constructor, Operator, Owner, Facility Manager
AIM	Asset Information Model
AIR	Asset Information Requirements
BCF	BIM Collaboration Format
BEP	BIM Execution Plan
BIM	Building Information Modelling
BIEG	BIM Interoperability Expert Group
BIMMM	BIM Maturity Matrix
BPxP	BIM Project Execution Plan
BS	British Standard
BSI	British Standard Institution
CDE	Common Data Environment
CI	Capitolato Informativo
CIC	Construction Industry Council
CMM	Capability Maturity Model
COBie	Construction Operations Building Information Exchange
CPIC	Construction Project Information Committee
DB	Design-Building
DBB	Design-Bid-Build
EAC	Engineering, Architecture and Construction
EIR	Employer Information Requirements
EIR	Exchange Information Requirements
EUPPD	European Union Public Procurement Directive
FM	Facility Manager
GIS	Geographic Information System
iBIM	Integrated Building Information Modelling
I-CMM	Interactive Capability Maturity Model
IFC	Industry Foundation Class
IM	Information Management
IPD	Integrated Project Delivery
IR	Information Requirements
ISO	International Organization for Standardization
KPI	Key Performance Indicators
LOD	Level of Development
MEP	Mechanical, Electrical and Plumbing
MIDP	Master Information Delivery Plan
NBS	National Building Specification
NGBO	National BIM Guide for Owners
NIBMS	National Building Information Model Standard
NIBS	National Institute of Building Science
NURBS	Non-Uniform Rational Basis Spline
oGI	Offerta di Gestione Informativa

OIR	Organisational Information Requirements
OPR	Owner's Project Requirements
OXML	Open EXtended Markup Language
PAS	Publicly Available Specification
pGI	Piano di Gestione Informativa
PhD	Doctor of Philosophy
PIM	Project Information Model
PIP	Project Implementation Plan
PIR	Project Information Requirements
PM	Project Manager
QA	Quality Assurance
QC	Quality Control
QS	Quantity Surveyors
RACI	Responsible, Accountable, Consulted, Informed
RIBA	Royal Institute of British Architects
SQL	Structured Query Language
TIDP	Task Information Delivery Plan
UNI	Ente Nazionale Italiano di Unificazione
WIP	Work In Progress
XML	EXtended Markup Language

APPENDICES

APPENDIX 1: EIR TEMPLATE

General Information	
Company name	
Project name	
Project code	
Project goals	
Project address	
Pan of work	Developed Workflow

Stakeholders' Contacts	
Client/Owner	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
BIM Manager	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
BIM Coordinator **Architects** Task team	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
Architect Designer Team Leader	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
BIM Coordinator **Structural Engineers** Task team	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:

Stakeholders' Contacts

Structural Engineer Team Leader	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
BIM Coordinator **MEP Engineers** Task team	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
MEP Engineer Team Leader	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
Contractor Main	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
Sub-Contractor	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
Facility Manager	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
Supplier 1	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:
Supplier 2	Name:
	Surname:
	Mobile:
	Office Telephone:
	Office Address:

STANDARDS		APPLICATION															
		EIR	Collaboration	Project Milestones	Archive Name Convention	Object Name Convention	File Name Convention	Plans	Classification	BEP	IFC	COBie	LOD	MODELS	CDE	Costs	Contracts
INDUSTRY	PAS 1192-2:2013		M												M		
	PAS 1192-3:2014														M		
	BS 1192-4:2014	M	M														
	BS EN ISO 19650-1:2018	M	M		M	M	M										
	BS EN ISO 19650-2:2018	M	M		M	M	M										
	NBS BIM Toolkit for Classification				O			O									
	IFC													M			
	COBie													M			
	BS 8541-1:2012					O								O			
	BS 8541-2:2011					O		O						O			
	BS 8541-3:2012																
	BS 8541-4:2012																
	AEC (UK) BIM Protocols																
	Uniclass 2015 (NBS Toolkit)					O								O			
	Omniclass 2015 (NBS Toolkit)					O								O			
PROJECT RELATED	Country building requirements																
	Evacuation plan requirements												O	O			
	Energy analysis requirements									O							
	…….																

M = Mandatory
O = Optional

Model Exchange Formats

Model	Software	Native Format	Model Exchange Format	Communication Exchange Format	Information Exchange Format	Drawing Package Format	Documents Package Format
Concept	Sketchup 2020	.skp	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Architectural	Archicad 2020	.pln/.pla	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Structural	Revit 2020	.rvt	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
MEP	Revit 2020	.rvt	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Federated	Navisworks 2020	.nwf/.nwd	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Federated for Submission	Navisworks 2020	.nwf/.nwd	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Federated for Construction	Navisworks 2020	.nwf/.nwd	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF
Model Viewer	Solibri Model Viewer	IFC (2x3)	IFC (2x3)	BCF	COBie (v.2.4)	PDF	PDF

CDE Platform

Autodesk 360

Main Folder Structure	Content
Work In Progress (WIP)	Contains unapproved information provided by each team or organisation for their in-house design team use only. A supplementary section may be used to hold additional information for contractors.

CDE Platform	
Autodesk 360	
Main Folder Structure	**Content**
Shared (comprehensive of client shared area)	Contains checked, reviewed and approved information ready to be used by other task teams, organisation and stakeholders as reference for their design. Once the information is checked, it is placed in the client area awaiting approval from the Client or their representative (BIM Manager).
Published	Contains the approved or accepted information by the Client, and it is ready to be used for authority submission, tender or construction.
Archived	This folder is used to store information and record of the projects for future uses.
CDE ownership should be shared between three people	

Coordinates	
Survey Coordinates	23°N 15' 56"
Model Coordinates	0.0.0

Level of Development

Model Object	Final LOD Required
Partition Walls	300
Floor Finish	300
Roof Finish	300
Doors	350
Windows	350
Columns Finish	200
Beams Finish	200
Furnishes	350
Structural Walls	350
Structural Floors	350
Columns	350
Beams	350
Pipes	400
Boiler	400
Air Conditioning System	400
Electrical System	400
Mechanical System	400

LOD	Specification according to BIMForum 2019 - Part I
100	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 other Model Elements. **BIMForum Interpretation**: LOD 100 elements are not geometric representations. Examples are information attached to other model elements or symbols showing the existence of a component but not its shape, size, or precise location. Any information derived from LOD 100 elements must be considered approximate.
200	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. **BIMForum interpretation**: At this LOD elements are generic placeholders. They may be recognizable as the components they represent, or they may be volumes for space reservation. Any information derived from LOD 200 elements must be considered approximate.
300	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. **BIMForum interpretation**: The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs. The project origin is defined and the element is located accurately with respect to the project origin.
350	The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, location, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element. **BIMForum interpretation**: Parts necessary for coordination of the element with nearby or attached elements are modeled. These parts will include such items as supports and connections. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs.
400	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element. **BIMForum interpretation**: An LOD 400 element is modeled at sufficient detail and accuracy for fabrication of the represented component. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs.

The facility Manager will set Operational and Maintenance parameters for the model according to project needs.

Role	Responsabilities																																		
	BIM Competencies Matrix	Project's team members maturity level assessment	OIR	AIR	PIR	EIR	BEP	Concept Model	Coordinate Supervise and Manage Processes	Settle and Coordinates Meetings	Coordinate and Supervise BIM Coordinators	Coordinate and Supervise Discipline Task Team	Architectural Model	Structural Model	MEP Model	Architectural Schedules Quantities Details Costs	Structural Schedules Quantities Details Costs	MEP Schedules Quantities Details Costs	Provide Specific Model Objects	Object's Library	Clash Detection Architectural Model	Clash Detection Structural Model	Clash Detection MEP Model	Quality Assurance Architectural Model	Quality Assurance Structural Model	Quality Assurance MEP Model	Clash Detection Federated Model	Quality Assurance Federated Model	Validation Federated Model	Clash Detection Federated Model for Submission	Quality Assurance Federated Model for Submission	Validation Federated Model for Submission	Clash Detection Federated Model for Construction	Quality Assurance Federated Model for Construction	Validation Federated Model for Submission	Shop Drawings
Client/Owner	C	C	C	C	C	C	C	C					C																							
BIM Manager (Architect)	R	R	R	R	R	R	R		R	R	R									R							R	R	R	R	R	R	R	R	R	
BIM Coordinator **Architects** Task team												R	C			R				C	R			R												
Architect Designer Team Leader					C	C	C	R					R			C				C																
BIM Coordinator **Structural Engineers** Task team												R		C			R			C		R			R											
Structural Engineer Team Leader					C	C	C							R			C			C																
BIM Coordinator **MEP Engineers** Task team												R			C			R		C			R			R										
MEP Engineer Team Leader					C	C	C								R			C		C																
Contractor Main					C	C	C																										C	C		R
Sub-Contractor																																	C	C		R
Facility Manager				C	C	C	C						C																				C	C		R
Supplier 1																			R	C																
Supplier 2																			R	C																

R = Responsible
C = Contribute

Data Segragation

Stage	Concept Model	Architectural Model	Structural Model	MEP Model
Concept Design	- Building Blocks; - Zones.			
Spatial Coordination		- Building Blocks; - Zones; - Levels.		
Modelling and Coordination		- Building Blocks; - Zones; - Levels; - External Walls - Internal Walls; - External Floors; - Internal Floors.	- Level Ground; - Level First; - Level Second; - Level Roof.	- Level Ground; - Level First; - Level Second; - Level Roof.
Detail		- Building Blocks; - Zones; - Levels; - External Bricks Walls - Internal Bricks Walls; - Internal Plasterboard Partitions; - External Stone Finish Floors; - External Timber Finish Floors; - Internal Terracotto Finish Floors; - Internal Wooden Finish Floor.	- Level Ground Concrete; - Level Ground Steel; - Level First Concrete; - Level First Steel; - Level Second Concrete; - Level Second Steel; - Level Roof Concrete; - Level Roof Steel.	- Level Ground Air Conditioning System, Electrical System, Mechanical System; - Level First Air Conditioning System, Electrical System, Mechanical System; - Level Second Air Conditioning System, Electrical System, Mechanical System; - Level Roof Air Conditioning System, Electrical System, Mechanical System.

CDE Data Security

	WIP					Shared						Published				Archived				
Role	Architectural	Structural	MEP	Contractor	Facility Management	Client Area	Magnager Area	Federated Model	Drawings	Documents	Contracts	Authorities Submissions	Published Drawings	Published Model	Published Documents	Federated Model	Drawings	Documents	Contracts	Submission to Authorities
Client/Owner						A					A	A	A	A	A	A	A	A	A	A
BIM Manager (Architect)						A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
BIM Coordinator Architects Task team	A							A	A	A		A	A	A	A					
Architect Designer Team Leader	A										A									
BIM Coordinator Structural Engineers Task team		A							A	A		A	A	A	A					
Structural Engineer Team Leader		A									A									
BIM Coordinator MEP Engineers Task team			A						A	A		A	A	A	A					
MEP Engineer Team Leader			A								A									
Contractor Main				A							A	A	A	A	A					
Sub-Contractor				A																
Facility Manager					A				A	A	A		A	A	A					

A = Access

Collaboration and Issues Management

The project is based on the IPD methodology, and a collaborative environment is settled and requested since the beginning. Daily the BIM Manager will receive Information from discipline BIM Coordinators, Contractor and facility manager to keep under control project's progresses and issues. Weekly BIM Coordiinators will run an internal task team clash detection between models and a quality control. Every Friday at 5.00pm the disciplines models must be uploaded in the CDE Shared folder in the sub-folder of 'Federated Model' for BIM Manager check. Every two weeks the BIM Manager will run a clash detection and quality control of the Federated model. After the clash detection a report of issues will be sand from the BIM Manager to BIM Coordinators and a workshop will take place. During the meetings the Coordinators should provide solutions for the reported issues.

Plan of Work

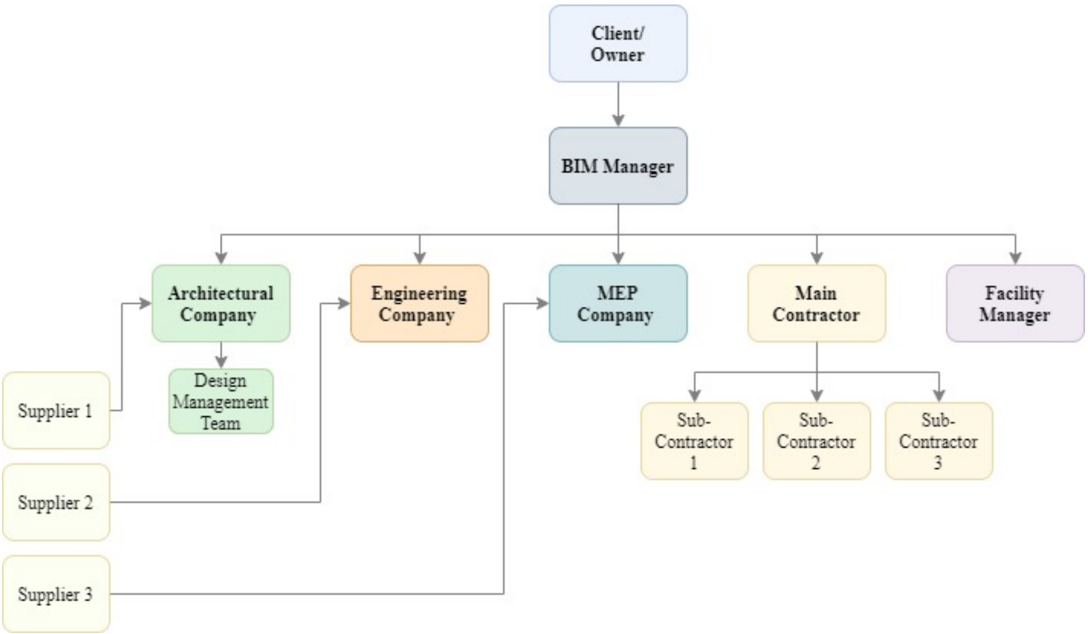
Stage	Milestone	Deliverables
Strategic Definition	**Pre Milestones**	- BIM Competencies Matrix; - Project's team members maturity level assessment
Preparation and Brief	**Pre Milestones**	- OIR - AIR - PIR - EIR - BEP
Concept Design	**Milestone 1**	Concept Model
Spatial Coordination	**Milestone 2**	- Architectural Model - Drawings
Modelling and Coordination	**Milestone 3**	- Architectural Model - Structural Model - MEP Model - Objects for Model - Federated Model - Drawings
	Milestone n	- Architectural Model - Structural Model - MEP Model - Model objects - Federated Model - Drawings
Automatic Licensing	**Milestone n+1**	- Federated Model for Submission - Drawings for Submission

Plan of Work

Stage	**Milestone**	**Deliverables**
Detail	**Milestone n+2**	-Diciplines Model - Federated Model for Construction - Drawings - Schedules - Details - Costs
Design for Construction	**Milestone n+3**	- Federated Model for Construction - Drawings - Schedules - Details - Costs

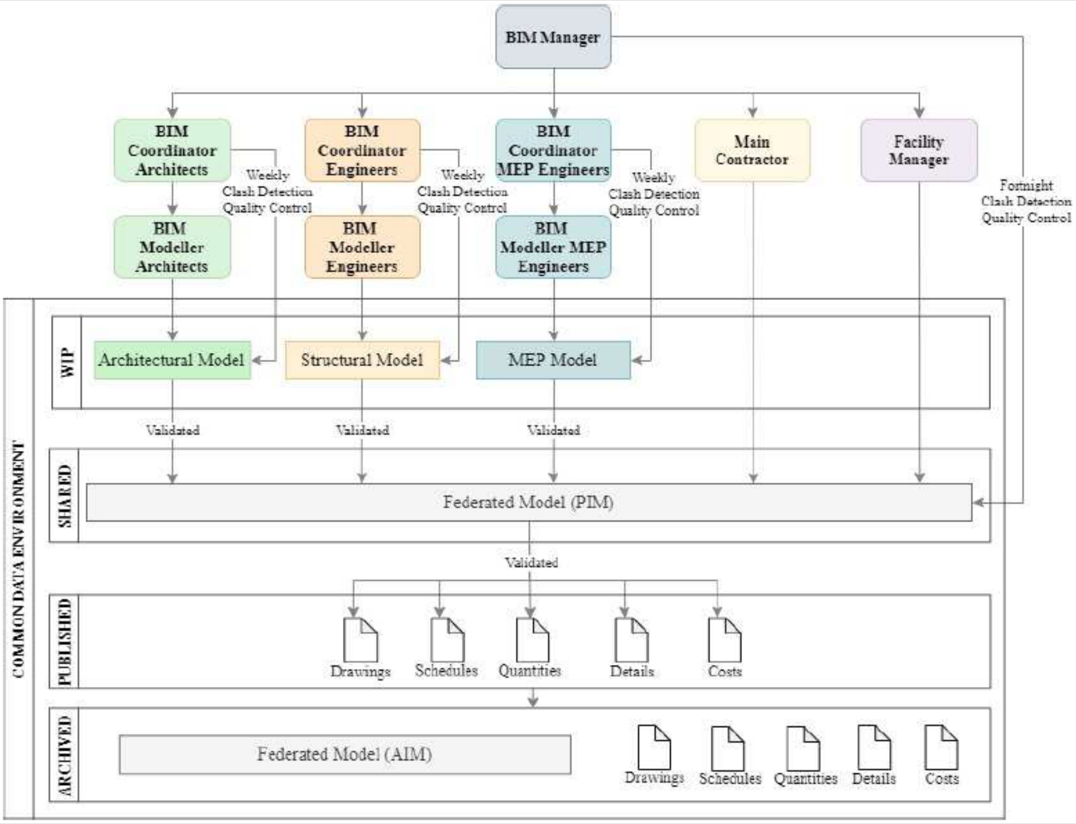
APPENDIX 2: BEP TEMPLATE

Organigram



Contacts are available in the EIR

BIM Coordination



BIM Roles	
BIM Manager	Develop a proper BIM Execution Plan, establish protocols, coordinate and keep updated the different teams and take care of the federated model. Assuring the information produced by the teams are compliant with the BEP and the EIR.
BIM Coordinator	Manage and control the single discipline model reviewing and approving the information produced.
BIM Modeller	Model creation and ownership, output the related documentation production. Ensuring all elements of the Information Model are fully coordinated with each other.

Collaboration and Issues Management

The project is based on the IPD methodology, and a collaborative environment is settled and requested since the beginning. Daily the BIM Manager will receive Information from discipline BIM Coordinators, Contractor and facility manager to keep under control project's progresses and issues. Weekly BIM Coordiinators will run an internal task team clash detection between models establishing a tolerance of 0,025m and a quality control. Every Friday at 5.00pm the disciplines models must be uploaded in the CDE Shared folder in the sub-folder of 'Federated Model' for BIM Manager check. Every two weeks the BIM Manager will run a clash detection and quality control of the Federated model. After the clash detection a report of issues will be sand from the BIM Manager to BIM Coordinators and a workshop will take place. During the meetings the Coordinators should provide solutions for the reported issues.

CDE Data Security

In order to not repeat information, this section could be found in the EIR document schedule 'Information Management'

Role	Deliverable																								
	Concept Model	Architectural Model	Structural Model	MEP Model	Architectural Schedules Quantities Details Costs	Structural Schedules Quantities Details Costs	MEP Schedules Quantities Details Costs	Provide Specific Model Objects	Object's Library	Clash Detection Architectural Model	Quality Assurance Architectural Model	Clash Detection Structural Model	Quality Assurance Structural Model	Clash Detection MEP Model	Quality Assurance MEP Model	Clash Detection Federated Model	Quality Assurance Federated Model	Validation Federated Model	Clash Detection Federated Model for Submission	Quality Assurance Federated Model for Submission	Validation Federated Model for Submission	Clash Detection Federated Model for Construction	Quality Assurance Federated Model for Construction	Validation Federated Model for Submission	Shop Drawings
Client/Owner	C	I																I			I			I	
BIM Consultant										I	I	I	I	I	I	I	I		I	I		I	I	I	I
BIM Manager (Architect)	I	I	I	I	I	I	I		A	I	I	I	I	I	I	A/R	A/R	A/R	A/R	A/R	A/R	A/R	A/R	A/R	A
BIM Coordinator **Architects** Task team		C			A				C	A/R	A/R					C	C	I	C	C	I	C	C	I	R
Architect Designer Team Leader	R	A	C	C						I	I					I	I		I	I		I	I		
BIM Modeller **Architects** Task team		R			R					C	C														
BIM Coordinator **Structural Engineers** Task team			C			A			C			A/R	A/R			C	C	I	C	C	I	C	C	I	R
Structural Engineer Team Leader		C	A	C								I	I			I	I		I	I		I	I		I
BIM Modeller **Structural Engineers** Task team			R			R						C	C												
BIM Coordinator **MEP Engineers** Task team				C			A		C					A/R	A/R	C	C	I	C	C	I	C	C	I	R
MEP Engineer Team Leader		C	C	A										I	I	I	I		I	I		I	I		I
BIM Modeller **MEP Engineers** Task team				R			R																		
Contractor Main																						C	C	I	R
Sub-Contractor																						C	C	I	R
Facility Manager		C	C	C																		C	C	I	R
Supplier 1								R	R																
Supplier 2								R	R																

R Responsible = Assigned to complete the task or deliverable.
A Accountable = Has final decision-making authority and accountability for completion. Only 1 per task.
C Consulted = An adviser, stakeholder, or subject matter expert who is consulted before a decision or action.
I Informed = Must be informed after a decision or action.
A/R Accountable and Responsible

Software Use and Version

Discipline	Model	Software	Version	Use
Architecture	Concept	Sketchup	2020	Model Production
	Architectural	Archicad	2020	Model Production
Structural Engineering	Structural	Tecla Structure	2019	Model Production
MEP Engineering	MEP	Revit	2020	Model Production
Energy Analysis	Analysis	Green Building Studio	2020	Model Production
	Analysis	Energy Plus	2020	Model Production
Architecture Structural Engineering MEP Engineering	Federated	Navisworks	2020	Quality Control, Navigation
	Federated for Submission	Navisworks	2020	Quality Control, Navigation
	Federated for Construction	Navisworks	2020	Quality Control, Navigation
Viewer	Model Viewer	Solibri Model Viewer	9.10.4.13	Control, model view
4D Simulation	Planning	MS Project	2020	Time Programming
5D Simulation	Control	Vico	2020	Cost Control
6D Simulation	Facility Management	AssetWORKS		Asset Management
6D Simulation	Facility Management	AssetWORKS		Maintenance

Software version, according to the contract, will be updated every two years with the help of the IT team to assure the preservation of information.

Naming Convention

Naming Convention follows NBS specification

File	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ Milestone n>_<Differentiator(Optional)>
Example	PR1-ARC_CompanyName_Arch-Mod_M3
BIM object	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ product code>_<Material>_<Differentiator>
Example	PR1-ARC_CompanyName_Door_External_Timber-F37_1200x2500
Individual layers in a multi-layered object	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ product code>_<Differentiator>
Example	PR1-ARC_CompanyName_Wall_External_StoneCladding-H15_1000x3000
Materials in the BIM platform	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ product code>_<Differentiator>
Example	PR1-STR_CompanyName_Wall_External_ReinforcementSteel-D58_30
Image files for materials (.bmp / .jpg)	<Project Code - Discipline>_<Source>_<Type>_<Subtype/ product code>_<Differentiator> _<ImageType> + file extension
Example	PR1-ARC_CompanyName_Floor_Internal_MarbleFinish-ZS5_200x500_Render-jpg

Object Library Parameters

Object parameters follows the NBS specification

NBS plug-in are available for Revit, Archicad and Vectorworks

NBS parameters correspondence for Revit, Archicad and Vectorworks:

Property Group	**Autodesk Revit**	**IFC, ArchiCad, Vectorworks, AECOsim**
IFC	IFC Parameters	Pset_
COBie	Other	COBie
NBS_General	General	NBS_General
NBS_Data	Data	NBS_Data

All objects developed or provided for the project will be stored inside the Object library in the CDE. Each object should comply NBS specification parameters as to be exported in IFC and COBie format. Thus, once the parameter are exported they are all stored in the right palace to guarantee the interoperability.

NBS specification already contains Operational and Maintenance parameters. The Facility Manager could agree on those parameters or add more of them according to project needs.

Level of Development

Architectural Model

Model Element	Concept Design	Spatial Coordination	Modelling and Coordination	Automatic Licensing	Detail	Design for Construction
SPATIAL						
Site boundaries, setbacks	100	100	200	200	200	200
Grids	100	100	200	200	200	200
Levels	100	100	200	200	200	200
Zones	100	100	300	300	300	300
Spaces, rooms	100	100	300	300	300	300
SITE						
Topography	100	100	200	200	300	300
Excavation			200	300	350	400
Stormwater			200	200	300	400
Services	100	100	200	200	300	400
Roads	100	100	100	100	200	300
Parking	100	100	100	100	200	300
Paths, paving	100	100	200	200	300	300
Walls, fencing	100	100	200	200	300	350
Soft landscaping		100	100	200	200	300
ENCLOSURE						
Roofing	100	100	200	200	300	350
Cladding			100	100	200	350
Column claddings			100	100	200	200
Curtain walls	100	100	100	100	200	200
Windows	100	100	200	200	350	400
External doors, openings						
INTERIOR						
Partitions	100	100	100	100	300	350
Internal doors, openings	100	100	100	100	300	350
Ceilings			100	100	200	300
Flooring	100	100	100	100	300	350
Balustrading	100	100	100	100	200	300
FURNITURE, FIXTURES and EQUIPMENT						
Casework, joinery		100	100	100	200	200
Fixtures		100	100	100	200	200
Fittings		100	100	100	200	200
Equipment (non-service)		100	100	100	200	200
Furniture		100	100	100	200	200

Structural Model						
Model Element	**Concept Design**	**Spatial Coordination**	**Modelling and Coordination**	**Automatic Licensing**	**Detail**	**Design for Construction**
SUBSTRUCTURE						
Footings		100	200	200	300	350
Retaining walls		100	200	200	300	350
Subsoil drainage		100	200	200	300	350
STRUCTURE						
Floor structures			200	200	300	350
Beams			200	200	300	350
Shaft openings			200	200	300	350
Stair & ramp structures			200	200	300	350
Walls – load bearing			200	200	300	350
Columns			200	200	300	350

MEP Model						
Model Element	**Concept Design**	**Spatial Coordination**	**Modelling and Coordination**	**Automatic Licensing**	**Detail**	**Design for Construction**
MECHANICAL						
Plant external			100	100	300	400
Plant internal			100	100	300	400
Services in risers		100	100	100	300	400
Louvers			100	100	300	400
Ductwork			100	100	300	400
Registers			100	100	300	400
Pipework			100	100	300	400
Controls			100	100	300	400
HYDRAULIC						
Plant & equipment			100	100	300	400
Sanitary fixtures		100	100	100	300	400
Pipework			100	100	300	400
Services in risers		100	100	100	300	400
FIRE PROTECTION						
Sprinklers			100	100	300	400
Pipework (main)			100	100	300	400
Pipework (branch)			100	100	300	400
Detection			100	100	300	400
EWIS / alarm systems			100	100	300	400
Hydrants			100	100	300	400
Extinguishers			100	100	300	400
Services in risers		100	100	100	300	400
ELECTRICAL						
Electrical fixtures			100	100	300	400

MEP Model						
Model Element	**Concept Design**	**Spatial Coordination**	**Modelling and Coordination**	**Automatic Licensing**	**Detail**	**Design for Construction**
Power outlets			100	100	300	400
Switch & distribution boards			100	100	300	400
Cable trays			100	100	300	400
Lighting		100	100	100	300	400
Light switches / controls			100	100	300	400
Communications			100	100	300	400
Security			100	100	300	400
Services in risers		100	100	100	300	400
CONVEYING						
Lifts, escalators		100	100	100	300	400

LOD	Specification according to BIMForum 2019 - Part I
100	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 other Model Elements. **BIMForum Interpretation**: LOD 100 elements are not geometric representations. Examples are information attached to other model elements or symbols showing the existence of a component but not its shape, size, or precise location. Any information derived from LOD 100 elements must be considered approximate.
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350	The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, location, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element. **BIMForum interpretation**: Parts necessary for coordination of the element with nearby or attached elements are modeled. These parts will include such items as supports and connections. The quantity, size, shape, location, and orientation of the

	element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs.
400	The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element. **BIMForum interpretation**: An LOD 400 element is modeled at sufficient detail and accuracy for fabrication of the represented component. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs.

Project Milestones

STAGE	Milestone	Date	Deliverables	Meeting Attendants
Concept Design	**Milestone 1**	**24/07/2020**	Concept Model	Client BIM Manager Architect
Spatial Coordination	**Milestone 2**	**30/08/2020**	Architectural Model	BIM Manager Architect Structural Engineer MEP Engineer Facility Manager
Modelling and Coordination	**Milestone 3**	**15/09/2020**	Architectural Model Structural Model MEP Model Federated Model	BIM Manager BIM Coordinator Architects Architect BIM Coordinator Structural Eng Structural Engineer BIM Coordinator MEP Eng MEP Engineer
	Milestone n	**30/09/2020**	Architectural Model Structural Model MEP Model Federated Model Drawings	BIM Manager BIM Coordinator Architects Architect BIM Coordinator Structural Eng Structural Engineer BIM Coordinator MEP Eng MEP Engineer
Licensing	**Milestone n + 1**	**15/10/2020**	Federated Model for Submission Drawings	BIM Manager BIM Coordinator Architects BIM Coordinator Structural Eng BIM Coordinator MEP Eng

Project Milestones

STAGE	Milestone	Date	Deliverables	Meeting Attendants
Detail	**Milestone n + 2**	**30/10/2020**	Architectural Model Structural Model MEP Model Federated Model for Construction Drawings Schedules Quantities Details Costs	BIM Manager BIM Coordinator Architects Architect BIM Coordinator Structural Eng Structural Engineer BIM Coordinator MEP Eng MEP Engineer
Design for Construction	**Milestone n + 3**	**15/11/2020**	Architectural Model Structural Model MEP Model Federated Model for Construction Drawings Schedules Quantities Details Costs	BIM Manager BIM Coordinator Architects BIM Coordinator Structural Eng BIM Coordinator MEP Eng Contractor Sub-Contractos Facility Manager
	Milestone n + 4	**30/11/2020**	Architectural Model Structural Model MEP Model Federated Model for Construction Drawings Schedules Quantities Details Costs	BIM Manager BIM Coordinator Architects BIM Coordinator Structural Eng BIM Coordinator MEP Eng Contractor Sub-Contractos Facility Manager

APPENDIX 3: VALIDATION INTERVIEW QUESTION LIST

QUESTIONS FOR CASE STUDY		
INTRODUCTION		- Explain the confidentiality of the interview
		- Ask to record
		- Explain our dissertation focus
		- Explain what is expected from the interviewed, the amount of question and time planned
		- Explain that we have already spoken with Tiago/Belfast University and João / Amsterdam Datacenter
TEAM	1.1	What are the main challenges in your evaluation of the competences of the team members of your company? In your experience, is there someone evaluating the all teams competencies? If yes, how?
	1.2	Is anyone requesting specific competences? Certified ones or not?
	1.3	What do you think about this roles matrix proposal?
	1.4	Who is in charge to write down the EIR and the BEP? The BIM Manager? How is the BIM manager role being attributed?
EIR	2.1	How have the BIM requirements been specified?
	2.2	In your opinion who should contribute to the set up of these requirements? Are all the parties (designers, owners, contractors, subcontractors, facility managers) involved? Is that an imposed process or is it a collaborative work?
	2.3	Should it be based on a specific guideline/rule or is it project related?
	2.4	What type of contract is generally used? (DB, DBB, IPD) Do you think that affect the BIM processes?
	2.5	Do you think requirements should be more generic or more specific? Do you foresee this process as a machine to machine procedure in the future?
CDE	3.1	In your opinion, do you think it is feasible to have only one CDE during the whole process of information management? If yes, who should be responsible for it?
	3.2	How do you choose the CDE for each project? Is it an employer requirements? If yes, do you have the chance to give your opinion about it?
AIR	4.1	Is it usual to require for information that will be used in the operation phase since the beginning? Or when do you think those information should be required?
	4.2	Is the facility manager involved in this definition of this AIR?

QUESTIONS FOR CASE STUDY

BEP	5.1	During the development of the BEP, are all the parties (designers, owners, contractors, subcontractors, facility managers) involved?
	5.2	How the LOD is established? By whom?
	5.3	Is it agreed on a software to avoid interoperability issues? Software and version?
	5.4	Do you generally use IFC as exchange formats? What do you think are its benefits?
	5.5	How is the data segregation managed?
	5.6	Do you generally use Cobie as exchange formats? What do you think are its benefits?
	5.7	Once you define Cobie as exchange format, how do you manage the information (Excel, xml)?
	5.8	How data security is dealt with?
	5.9	How do you define the intellectual property of the model?
	5.10	Do you set out protocol for issues? (clash detection, lack of information, quality assurance)

TIDP	6.1	Do you have a Task information delivery plan? Who controls it and verifies its fulfillment?
	6.2	Do you have a master information delivery plan? How do they collect and decide for information delivery?

MODEL	7.1	Does each team deliver one model?
	7.2	How to check model quality? What is verified? Who is the responsible for it?
	7.3	Who runs the clash detection? How is the results of the clash detection transferred to the other team members?

DESIGN STAGE	8.1	Are all stakeholders involved here? (designers, owners, contractors, subcontractors, facility managers)
	8.2	How is the communication of issues? Is there a predefined hierarchy?
	8.3	What are the main problems in this stage working with BIM?

PLAN AND COST	9.1	Who is responsible for the quantity take-off? Are the quantity take-offs validated by someone?
	9.2	Is the WBS defined in the beginning of the project? Is a requirement from the contractor at the beginning of the project (defined in the BEP?)?
	9.3	Are the quantity take-offs according to the WBS?
	9.4	Who is responsible for the 5D (cost)?

QUESTIONS FOR CASE STUDY		
	9.5	Are the parameters in model used for planning and cost added in the Design Stage? Or is it changed by someone else in the "construction planning" phase?
	9.6	What software is used on BIM cost and planning? How is the interoperability between them and the models from Design Stage?
CONSTRUCTION	10.1	What software is used on BIM to Field? How do you visualize the model on site?
	10.2	What is the use of the model on site?
	10.3	Do you think other uses of the model could be applied on site?
	10.4	How do you communicate from the construction site when there are issues or request of information?
	10.5	How do you think it could be improved? Centralized in an IM platform?
	10.6	How are the as-built information recorded? In a model? In paper? Through pictures?
	10.7	Who is the responsible for the as-built model in the study case?
	10.8	If the responsible for the as-built model is not the design team, do you think other stakeholder should start the model from zero?
HANDOVER	11.1	How is the handover to the facility managers? A CDE? All information on model?
OPERATIONS	12.1	Does the facility manager requires in the beginning the format he needs the data so he can use in his O&M software?
	12.2	Is the model exported to an external database to be used by the FM?
	12.3	Do you think the contractor should make the link of the model whit a database or should the FM receive and deal with models and documentation?
	12.4	How is the interoperability between the model (data from previous phases) and O&M systems?
	12.5	In your experience, did you find any issues while using COBie?
MODEL	13.1	How does the model evolve from one phase to another? Who is responsible to exchange the model information from one phase to another?
	13.2	How and where the model is stored after the project end?