BIM Execution Plan Proposal

Synergies with PMBOK

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Resumo

Building Information Modeling (BIM) está cada vez mais generalizado a nível internacional e nacional, devendo existir documentos para apoiar a implementação desta metodologia. Para uma implementação apropriada do BIM é necessário desenvolver um plano detalhado, indicando os fatores-chave a seguir pela equipa durante o projeto, levando em consideração todas as normas BIM e os valores e os interesses da empresa.

O plano de execução BIM desenvolvido na dissertação foi configurado para assistir as organizações na gestão de um projeto colaborativo BIM. Para o desenvolvimento deste plano foi feita uma investigação minuciosa, primeiramente focada nos planos e normas existentes relacionados com BIM, com a intenção de tirar proveito de suas melhores características.

Sendo o plano de execução BIM nada mais do que um plano de execução de um projeto é possível fazer uma analogia entre o campo da gestão de projetos e o domínio BIM. Sendo que um dos objetivos cumpridos foi melhorar a metodologia entre estes dois campos através da sua comparação. Assim, e após análise dos documentos relacionados com o BIM, analisou-se as possíveis contribuições que as boas práticas da gestão de projetos poderiam ter sobre o desenvolvimento do plano, numa tentativa de reconhecer qualidades comuns e integrar tais práticas em uma metodologia capaz de potenciar os resultados positivos no ciclo de vida do edifício.

Além disso o plano proposto está a servir de base para a criação de uma “especificação técnica” através do “Comité de normalização BIM” de modo a assistir as firmas portuguesas a implementar o BIM.

Palavras-chave: Building Information Modeling (BIM); Plano de Execução BIM; Gestão de Projetos; Corpo de Conhecimentos da Gestão de Projetos.

Abstract

Building Information Modeling (BIM) is evermore generalized at an international and national level, therefore there should exist documents to support its implementation. To an appropriate BIM implementation it is necessary to develop a detailed plan, indicating the key factors for the team to follow during the project, which should take in consideration all the BIM standards and the company values.

The BIM execution plan developed in the dissertation was configured to assist the organizations in the process of managing a BIM collaborative project. For the development of this plan it was made a thorough research, focused primarily on already developed BIM-related plans and standards, with the intention of taking advantage of their best characteristics.

The BIM execution plan is nothing more than a project execution plan and consequently it is possible to make an analogy between the field of project management and the BIM domain. Being that one of the accomplished objectives was to increase the bibliography relating project management and BIM trough their comparison. For the creation of BEP there were analyzed the possible contributions that the existing practices related to project management could have on the development of the plan, in an attempt to recognize common qualities and integrate such practices into a methodology able to potentiate the positive results in the building´s life cycle.

In addition the proposed BEP is serving as a basis to the creation of a "technical specification" by the "Comité de normalização BIM" in order of assisting the AEC firms implementing BIM.

Keywords: Building Information Modeling (BIM); BIM Execution Plan (BEP); Project Management; Project Management Body of Knowledge (PMBOK).

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1.1- Background

The construction industry has experienced a gradual decrease in its labor productivity since the early 1960, which means that for the same amount of work the number of hours of employees is tending to increase, even with the technological advancement. This indicates that construction industry is lacking the development of labor saving ideas (Hergunsel, 2011). In contrast, other industrial sectors are increasing their labor productivity. Figure 1.1 shows a comparison between the construction industry and other industries productivity evaluated in the United States. By analyzing the graphic it is notorious that while the construction industry has a decrease of productivity, the other industries have their labor productivity increased.

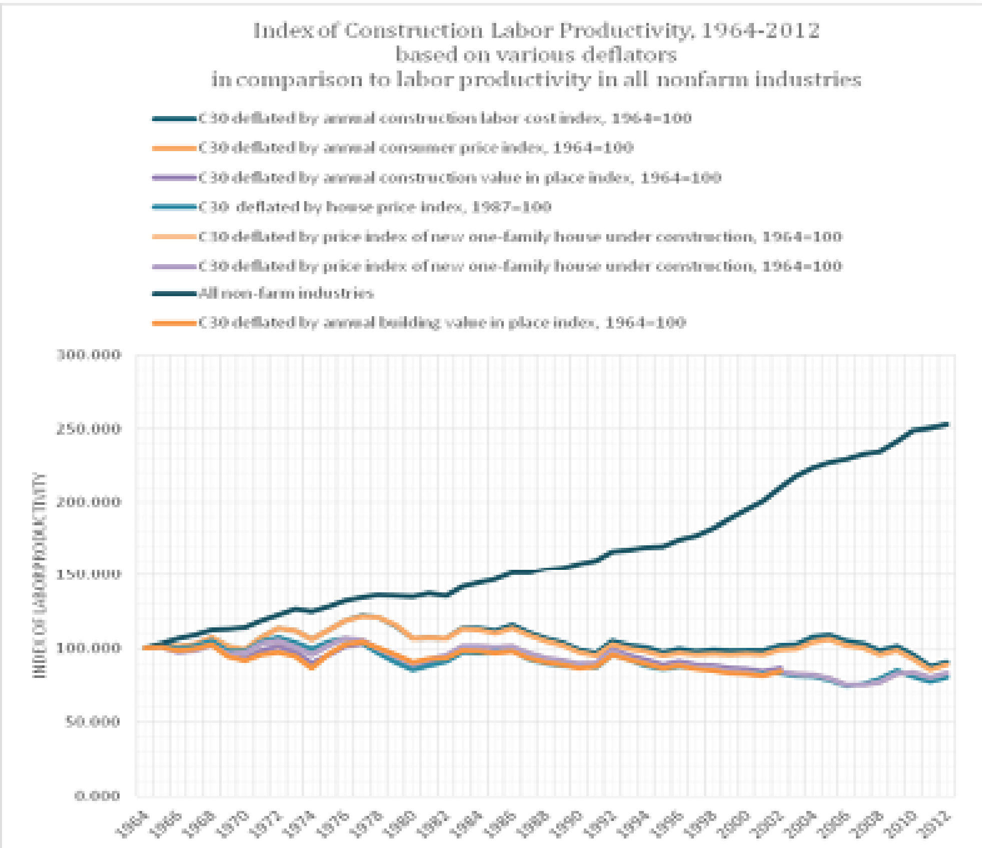


Figure 1.1- Labor productivity for comparator industries evaluated in the US (Teicholz, 2013)

The main causes of the lack of labor productivity in the construction industry according to Teicholz (2013) are: the unique work products built by varying teams under varying site, regulatory and weather conditions; the industry where significant output consists of remodel and renovation of existing facilities as opposed to new work, which means that the conditions of the work are more difficult and thus there is a decrease of the productivity; the procurement system that is often based on a competitive rather than collaborative solution, being there is a lack of collaboration between the design and construction phase, where the team member try to protect themselves from impacts caused by errors or omissions and the sub-contractors try to benefit from extra work (Teicholz, 2013). It can also be verified that construction projects are becoming much more complex and difficult to manage (Travaglini et al., 2014), being that division among the various stakeholders the main cause of the current construction industry state (Isikdag and Underwood, 2010).

As a response, Information and Communication Technology (ICT) has been developing at a very fast pace (Travaglini et al., 2014). The major shift in ICT in the Architecture Engineering and Construction (AEC) sector is the spread of Building Information Modeling (BIM) (Bryde, Broquetas, and Volm, 2013). BIM is a revolutionary technology and methodology that has quickly transformed the way buildings are conceived, designed, constructed and operated (Hardin, 2009). BIM has not only arrived in the AEC industry but has literally taken it over, which is particularly remarkable in an industry that has historically been notoriously resistant to change (Eastman et al., 2011).

BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle, being defined as existing from earliest conception to demolition (Azhar et al., 2012). A BIM model carries all information related to the building, including its physical and functional characteristics and project life cycle information, in a series of “smart objects” (Azhar et al., 2008), meaning that BIM contains all the necessary information in the form of data repository, which supports the decision making process of the stakeholders. A basic premise of BIM is collaboration and integration of all the different stakeholders at different phases of the life cycle of a facility to include, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder (NBIMS, 2010).

BIM means not only using three-dimensional intelligent models but also making significant changes in the workflow and project delivery processes (Hardin, 2009). BIM is a mean to support the design, construction and facility management phases of a building, which needs to be sustained by agreements on project responsibility between the stakeholders of a project (Thomassen, 2011). This means that BIM supports all the project deliveries agreements including design/ bid/ build, being that these agreements are related to a flow where the work is handed over in phases.

Although BIM can be used with all kinds of project delivery systems, many believe that its benefits are greatest when coupled with more collaborative approaches to project delivery (Wickersham, 2009). In that sense there should be considered newer delivery agreements like the integrated project delivery (IPD), based on more integrated relationships between the different supply chain actors with the objective to induce more efficient designs (Eastman et al., 2011). Certainly, integrated projects can be done without BIM and BIM can be used with non-integrated processes, however, the full potential of both IPD and BIM are achieved only when they are used together (AIA California Council, 2007).

Looking at BIM as a system and a methodology to support efficient information management, it can be considered a project management matter (Travaglini et al., 2014). Construction and development projects involve the coordinated actions of many different professionals and specialists to achieve defined objectives, and therefore the task of the project management is to bring the professionals and specialist into the project team at the right time to enable them to make their best possible contribution (Chartered Institute of Building, 2014). In this sense it is essential to carefully structure the BIM implementation in a way that all the project stages are well defined right from the start of the project and the entering point for the specialists to bring their knowledge and experience into the project team is clear (Chartered Institute of Building, 2014).

The different bodies of knowledge of project management and experience have the potential to make important contributions to decisions at every stage of projects, and therefore they can contribute in creating a plan for implementing BIM and managing BIM projects. Project management manages the full development process, from the client's idea to funding coordination and acquirement of planning and statutory controls approval, sustainability, design delivery, through to the selection and procurement of the project team, construction, commissioning, handover, review, to facilities management coordination (Chartered Institute of Building, 2014).

1.2- Dissertation scope and objectives

To successfully implement BIM it is necessary to create strategies of how BIM is going to be used on the project, taking into account all the current BIM standards and methodologies. To create those strategies it should be created a detailed and comprehensive plan that will ensure that all parties are clearly aware of the opportunities and responsibilities associated with the incorporation of BIM into the project workflow (CIC, 2011). Recognizing these needs this dissertation has the aim of contributing to the implementation and standardization of the BIM methodology among the current and future stakeholders of the AEC industry.

The core objective of this dissertation is to propose strategies to implement BIM by developing a BIM Execution Plan, in order to approach BIM collaborative processes with project management best practices. This will be done by analyzing the existing guidelines and protocols of different countries, and the possible influences that the project management bodies of knowledge can have on BIM implementation. Along with this objective, interviews and discussions with experts on BIM and project management areas will be conducted, in order of accessing the viability of the results obtained and to further develop the plan.

Although the project management is a large discussed area with lots of bibliography, its application to the BIM implementation is yet underdeveloped. In that way, one of the objectives of this dissertation is to prove that the information existent at the project management bodies of knowledge can be integrated at a BIM implementation and, therefore, should be considered when strategizing and implementing a BIM Execution Plan (BEP). Thus, for the development of the BEP it will be analyzed the common characteristic between the two areas and assessed which practices, described within the project management best practices have a positive impact in the implementation of BIM.

Lastly this dissertation has the objective of taking the proposed BIM Execution Pan to the “Comité de normalização BIM”, to serve as basis to a technical specification, that will assist the Portuguese AEC firms on implementing BIM.

1.3- Methodology

The investigation of this dissertation is made as thorough as possible, from the definition and analysis of BIM and its implementation plans, to the study of the project management best practices, how they are organized, and possible impacts on a project. Afterward, it is conducted a study and comparison between the project management best practices and the existent BIM execution plans, with the objective of developing an integrated BIM execution plan. Thus, the considered methodology contemplates the main topics:

- Literature Review: in a first instance it is conducted the study of BIM and the correspondent existent protocols, focusing on the BIM Execution Plans. The information of BIM and its protocols are assembled from the existing guidelines and protocols of some countries, and from the search of articles from data bases, namely google scholar.
  In the second part of the literature review it is described the main bodies of knowledge relating project management, and it is made a comparison between them to determine which can influence the most, in a positive way, the BIM Execution Plan.
- Comparison between BIM Execution Plan and Project Management Body of Knowledge: with the results from the literature review, a comparison between the existing BIM execution Plans and the project management body of knowledge is made. In order to do that the main areas of PMBOK are organized at tables and it is made the comparison of each area, taking into account what is already contemplated at the existent BEPs and what does not concern that area. Afterward, it is

discussed what processes of each area of project management can be contemplated and that have a positive impact in the creation of a plan to implement BIM.

- BIM Execution Plan improvement based on Project Management Best Practices: at this chapter it is proposed a BIM Execution Plan guide. For the development of this guide a multi-step research was made, firstly by thoroughly analyzing the existing planning documents already mentioned at chapter 2, secondly by considering the results of interviews performed with AEC professionals well recognized by their national and international experiences, and thirdly by analyzing the existent documents about project management and the results from the analysis made at chapter 4. The results retrieved from this bibliographical review and the interviews performed were analyzed and optimized for the creation of this BEP.

1.4- Dissertation Structure

The dissertation is organized into five chapters, reflecting the proposed methodology, being that the first one consists of this introduction. Chapter 2 presents the literature review, which is divided in two main parts, the first relating to BIM protocols and mainly to the BIM Execution Plan. These are put into context and it is characterized the different approaches to the BIM project and the various stages and teams involved in its development. The literature review starts with the definition of the BIM concept, with the description of the main aspects related with its implementation, namely the main objectives that an organization may have to implement BIM, and the major difficulties and potentialities that it can have. Furthermore it is given a closer attention to the existent BIM protocols with a bigger incidence on the BIM Execution Plan, by analyzing the current trends, the existent plans with the analysis of the most common features that they have. In addition it is made a brief description of two of the most recognized plans to better integrate them into the dissertation.

At the second part of the literature review it is described the main bodies of knowledge relating project management, along with the main areas of knowledge and processes that they possess. Furthermore, it is reviewed the existing bibliography relating project management and BIM to further understand the possible synergies between them.

Chapter 3 performs a comparison between the project management body of knowledge and the Building Information Modeling Project Execution Planning Guide (CIC, 2011) to discuss which practices of project management can be inserted or developed in order of improving the existent BIM Execution Plan.

Chapter 4 presents the proposed BIM Execution Plan (BEP) guide. The chapter begins with a brief description of the BEP and advances to the study of the fundamental issues regarding the BIM implementation, complemented with strategies to complete the plan. The chapter outlines a twelve point method to create a BIM Execution Plan for the stakeholders and project teams to follow during the implementation of BIM. In each point there is a theoretical clarification and a justification of the decisions made, along with some examples of how the BEP should be fulfilled.

Chapter 5 presents the main conclusions of the developed work, the acknowledged limitations, and possible future developments.

2- Literature Review

2.1- Building Information Management

Representations of the building information have always existed via separated applications, in spite of the paradigm being currently shifting to a more integrated solution. The purpose to represent all the needed information in order to describe buildings in an integrated building information model has always been present, being a way to build a more comprehensive solution with better communication and standards. The object-oriented tools to build such a model have been available for some time, but the need to integrate the parties involved in the process, and the ways in which their information is organized, have been a limitation on the widespread use of building information models (Howard and Bjork, 2007).

Currently, BIM still has different definitions for different professionals, being verified that there is a misunderstanding at three different levels: for some professionals BIM is a software application, for others it is a process for designing and documenting building information, and for others it is a whole new approach to the profession which requires the implementation of new policies, contracts and relationships amongst project stakeholders (Aranda-Mena et al., 2009). A definition is that BIM as lifecycle evaluation concept consists of interacting policies, processes and technologies that focus on creating and reusing consistent digital information by the stakeholders throughout the building lifecycle (Arayici et al., 2010, Succar, 2009a). It makes explicit the interdependency that exists between structure, architectural layout and mechanical, electrical and hydraulic services by technologically coupling project organizations together (Love et al., 2011).

An interesting perspective to BIM is its multidimensional capacity. This multidimensional capacity of BIM is defined as “nD” modelling, which is an extension of the building information model, incorporating multi-aspects of design information required at each stage of the lifecycle of a building facility (Aouad et al., 2005). 5D BIM is traditionally understood as BIM that includes, besides the 3D model, scheduling information (the 4th D) and information for estimating the project costs from the model (the 5th D) (Bryde et al., 2012). Therefore, BIM is a process focused on the development, use and transfer of a digital information model of a building project to improve the design, construction and operations of a project or portfolio of facilities (CIC, 2011). Consequently, the stakeholders have a platform to share information during the lifecycle of the building, which increases the collaborative process and improves the quality of the stakeholders´ projects.

The use of BIM can be due to its numerous benefits in a construction project. These can include: early collaborative decision-making; increased design clearness; stronger relation between design and costs; higher predictability of performance; and real-time data sharing between all disciplines (Navendren et al., 2014). Beyond these are also specific benefits to the various project participants like clients, designers and contractors. BIM has a potential use at all stages of the project life-cycle: it can be used by the owner to understand project needs, by the design team to analyze, design and develop the project; by the contractor to manage the construction of the project; and by the facility manager during operation and decommissioning phases (Bryde et al., 2013).

Besides all the advantages there are still some challenges in the implementation of BIM. Some of the challenges include: overcoming the endemic resistance to change, adaptation to traditional and existing processes and task workflows, and awareness and clear understanding of the responsibilities of different actors in a typical project organization (Eastman et al., 2011). In addition there is the implementation issue, as the effective use of BIM requires that changes are made to almost every aspect of a firm´s business. It requires a thorough understanding and a plan for implementation before the conversion can begin (Eastman et al., 2011).

2.2- BIM Execution Plan

BIM Protocols are documents or instructions in either textual or graphical format, paper or digital format that provide detailed steps or conditions to reach a goal or deliver a measureable outcome (Kassem et. al, 2014). The existing protocols are reviewed in terms of their coverage of three fields (technology, process and policy) and their target audience (industry, project, and enterprise) (Kassem et. al, 2014). The protocols aimed at industry level represent the protocols consisting of Level 1 BIM process maps representing the top-level steps required to create for a specific BIM Use. Protocols aimed at enterprise level are mostly concerned with the roles and responsibilities of stakeholders and level of details to be produced in different BIM Uses are agreed upon (Kassem et. al, 2014). The project level has greater details and includes also the implementation variables required to achieve the desired efficiency of the specific project.

Although the enterprise and project standards can be based on industry standards, the enterprise or project level standards are very deeply related to managerial issues including corporate or project strategies or policies based on specific business requirements (Jung et.al, 2010). A list of BIM protocols with their domain and target is described at Table 2.1 and Table 2.2.

Table 2.1- BIM protocols with their correspondent target (adapted from Kassem et.al, 2014)

Protocol	Target		Brief description
	Enterprise	Industry	
USACE, BIM Project Execution Plan (U.S., 2006)	Only to be used by the USACE		Protocols for implementing BIM in the U.S. Army Corps of Engineer's civil works and military construction processes with a focus on operation phase
The State of Ohio BIM Protocols (U.S., 2014)	To be used by building owners		General guidelines for building owners (requests for qualifications, agreements, bidding requirements, contracts)
Penn State University – Project Execution Planning Guide, Version 2.1 (U.S., 2011)		To be adapted by anyone who is using BIM	Guidelines to develop a plan to implement BIM in a project
New York City Council – BIM guidelines (U.S., 2012)	To be used by municipal agencies		Basic guidelines for use of BIM for municipal agencies (General information, BIM Use and requirements, submission and deliverables)
CIC BIM Protocol (U.K., 2013)		Standard Protocol for use in projects using Building Information Models	Guides that identify model-based requirements to be produced, permitted uses of models, levels of development and other contractual requirements
RIBA: BIM Overlay to the RIBA Outline (U.K., 2012)		To be used by those who follow the RIBA plan of word and are using BIM	An overview of how BIM alter the RIBA plan of work.
CRC-CI national guidelines for digital modeling (AU, 2009)		Protocol be followed by any BIM Users	Guidelines for creation, maintenance, modeling procedures and implementation on large projects
Singapore BIM Guide, Version 2.0 (SG, 2013)		Guidelines to be used by anyone using BIM	Guidelines for mono and multi-disciplinary modeling and collaboration
Statsbygg Building Information Modelling Manual Version 1.2	To be used on projects developed at areas managed by Statsbygg		Describe Statsbygg's requirements in respect of Building Information Models (BIM) in the open Industry Foundation Classes (IFC) format

Table 2.2- BIM protocols and their correspondent domain (adapted from Kassem et.al, 2014)

Protocol	Domain		
	Technology	Process	Policy
USACE, BIM Project Execution Plan (U.S., 2006)		Procedures to make a BIM Execution Plan	
The State of Ohio BIM Protocols (U.S., 2014)			Guidelines to ensure that building owners know what they should include in their documents
Penn State University – Project Execution Planning Guide, Version 2.1 (U.S., 2011)		Procedures to make a BIM Execution Plan	
New York City Council – BIM guidelines (U.S., 2012)			Guidelines for the consistent development and use of BIM
CIC BIM Protocol (U.K., 2013)		Identifies the BIM models that are required to be produced	Puts into place specific obligations, liabilities and associated limitations on the use of the models
RIBA: BIM Overlay to the RIBA Outline (U.K., 2012)			Guides the use of BIM in the context of the current RIBA Plan of Work
CRC-CI national guidelines for digital modeling (AU, 2009)		Provides and guides for key areas of model creation and development, and the move to simulation and performance measurement	
Singapore BIM Guide, Version 2.0 (SG, 2013)		Outline the various possible deliverables, processes and personnel/ professionals involved when using BIM	
Statsbygg Building Information Modelling Manual Version 1.2	Maps BIM requirements and the technology competency areas relevant to the achievement of those BIM requirements		

To an appropriate BIM implementation it is necessary to develop a detailed plan, which should take in consideration all the BIM standards and the company values and interests. The BIM Execution Plan is a protocol that can be either at industry or enterprise level and indicates the key factors for the team to follow during the project, acknowledging the project constraints, the stakeholders' agreements and requirements, and the technical and collaborative aspects to consider during the project. This plan defines the scope of BIM implementation and information exchanges, identifies the process flow for BIM tasks, describes the required infrastructure for support and provides a better understanding of goals (Akintoye et al. 2012). In addition, it helps to define and understand the responsibilities of each personnel, teams, department, and management, as well as in reducing unknown variables with competence to schedule and outline expected training and resources required for construction management (Fisher, 2011). The Computer Integrated Construction (CIC, 2011) identified some key aspects of BIM implementation on a project and within the organizations. These are organized at Table 2.3, accompanied with a brief description.

Table 2.3- Key aspects of BIM Execution Plan (adapted from CIC, 2011)

key aspects	Brief description
Project Goals/BIM Objectives (1)	List of the BIM Goals, along with specific information on the selected BIM Uses
BIM Process Design (2)	Creation of the overview map of the BIM Uses, a more detailed map of each of the BIM Uses, a description of any elements on each map, and documentation of the Information Exchange Requirements
BIM Scope Definitions (3)	Define the requirements, responsible parties and the incorporation on the schedule of selected BIM deliverables
Delivery Strategy/Contract (4)	Define the delivery approach
Organizational Roles and Responsibilities (5)	Define the roles of each organization along with responsibilities
Communication Procedures (6)	Define the electronic and meeting communications procedures
Technology Infrastructure Needs (7)	Define the appropriate hardware and software
Model Quality Control Procedures (8)	Define how the model is set-up, organized, communicated and controlled. Create control procedures
Project Reference Information (9)	Define the critical project overview information and the key project contacts

There is not a universal BIM execution plan, being revealed that most of the times different countries have different protocols or a different set of rules. Table 2.4 enumerates the main BEPs developed and practiced worldwide, aimed at industry level (more general), and shows which of the key aspects are contemplated (marked with an “x”). It should be taken in consideration that an aspect is only considered contemplated if all the features in its description are in the BEP. The BEPs in the table are compared with the BIM Execution Planning Guide (CIC, 2011), which was made by the same organization that created the considered key aspects and therefore it is considered the most complete, serving as the basis of comparison between all the BIM execution Plans.

Table 2.4- BIM Execution Plans

BIM Execution Plan	Country, year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
BIM Execution Planning Guide – Version 2	U.S., 2011	x	x	x	x	x	x	x	x	x
AEC (UK) BIM Protocol Project Execution Plan	UK, 2012	x	-	x	x	-	x	x	x	x
BIM Essential Guide – For BIM Execution Plan	Singapore, 2013	x	-	-	x	x	x	x	x	x
MIT BIM Execution Plan v3.2	U.S., 2010	x	x	x	x	x	x	x	x	x
Guide to BIM Execution Planning	U.S., 2013	x	x	x	x	x	x	x	x	-
Princeton University BIM Execution Plan Template	U.S., 2012	x	-	x	x	x	x	x	-	-

Table 2.4 was formulated considering six BIM execution plans. Most of the identified features are in accordance, despite the lack of one or two key aspects in the majority of BEPs. Although it is a good way to compare the BEPs, the table is limited by some more general key aspects, being that a BEP can have some characteristics of the mentioned key aspect but not in enough detail to be considered completed when compared with the aspect description. One example of this is that in the “Princeton University BIM Execution Plan Template” there are indications to sequence the models but not the level of detail of the information exchange or the maps of the BIM Uses, and therefore it is not considered having the “BIM process design” key aspect.

After comparing all the BIM Execution Plans it will be developed a more complex analysis of the BIM Execution Planning Guide, as it has all the key aspects and it is one of the few that, besides the BEP template, also has a guide attached to the plan, making it easier to understand and read. Also, the AEC (UK) BIM Protocol Project Execution Plan is going to be analyzed as it has a great portion of key aspects and well developed. Note that, even though the MIT BIM Execution Plan has all the key aspects, it is not going to be studied in further detail as it is very similar to the BIM Execution Planning Guide.

2.2.1- Building Information Modeling Project Execution Planning Guide

The first BEP to be analyzed in more detail is the BIM Execution Planning Guide (CIC, 2011). At Table 2.5 it is developed an overview of the BEP, being the points explained in a deeper way later.

This guide outlines a four step procedure to develop a detailed BIM Plan. It is intended to be a structured process in order to develop detailed and consistent plans for projects. The four steps consist of identifying the appropriate BIM goals and uses in a project, designing the BIM execution process, defining the BIM deliverables, and identifying the supporting infrastructure to successfully implement the plan.

Table 2.5- Main points of Building Information Modeling Project Execution Planning Guide

Building Information Modeling Project Execution Planning Guide (version 2.1)			
Identify BIM Uses And Goals	**Design BIM Project Execution Process**	**Develop Information Exchanges**	**Define Supporting Infrastructure For BIM Implementation**
Defining the BIM Goals for the Project	Mapping the Project Execution Process	Pulling the Information Through the Project	BIM Project Execution Plan Overview
Description of BIM Uses	Create a BIM Overview Map (Level 1)	Complete the Information Exchange Worksheet	Project Information
Begin with the End in Mind	Create a Detailed BIM Use Map (Level 2)		Key Project Contacts
BIM Use Selection Procedure	Symbols Used for Process Map Representation		Project BIM Goals / BIM Uses
			Organizational Roles and Staffing
			BIM Process Design
			BIM Information Exchanges
			BIM and Facility Data Requirements
			Collaboration Procedures
			Define specific collaboration activities
			Quality Control
			Technology Infrastructure Needs
			Model Structure
			Project Deliverables

2.2.1.1- Identify BIM Uses and Goals

The first part of the BIM Project Execution Planning Guide is to identify BIM goals and uses in order to provide a method for identifying appropriate BIM Uses for project implementation. This should be started by defining the BIM goals for the project, where these goals should be specific to the project at hand, measureable, and strive to improve the successes of the planning, design, construction, and operations of the facility. Some goals should relate to general project performance including reducing the project schedule duration or cost and increase the overall quality of the project. Other goals may target the efficiency of specific tasks to allow for overall time or cost savings by the project participants.

After the goals are defined, this guide describes the BIM Uses. To ease that task, the guide offers a list of twenty-five BIM Uses (Annex 2), organized by project phase of project development. Each description includes an overview of the BIM Use, potential value, required team competencies, and selected resources that can be referenced for additional information about the BIM Use. For BIM to be implemented successfully, it is critical that team members understand the impacts of the information that they are developing. The information can have an impact in the methods used to develop the model, or identify quality control issues related to the data accuracy for tasks relying on the information. This reveals the importance of structuring the ideas to identify the appropriate uses of BIM by beginning with the potential end-uses of the information in the model. By considering the later phases of a project, in order to understand which information will be valuable to those phases, it is unveiled the downstream desired for the use of information that should be supported by earlier processes in the lifecycle of the project. By doing this the team can identify reusable project information and important information exchanges.

To select the BIM Uses the team must identify the tasks that are going to be performed using BIM, by focusing on the desired outcomes for the overall process. Therefore, the team should identify the value for each described BIM Use to each project phase by providing a high, medium or low priority to every Use. To ease the BIM Use review process, this guide provides a BIM Use Selection Worksheet that includes a list of the potential BIM Uses, along with fields to review the value, responsible party, capabilities, additional notes, and the decision of the team on whether to implement the BIM Use or not.

To complete the BIM Use Selection Worksheet, the team should proceed with the key project stakeholders to fill the necessary steps. They should start by identifying the potential BIM Uses and consider their relationship with the project goals. Then it is necessary to identify at least one responsible party for each BIM Use, the responsible parties can include any team member involved in the Use, along with any potential participants needed. Then it is required to rate the competences of each party for each BIM Use. To do so it is necessary to split the competences in the following categories: resources, where it is assessed if the organization has the needed resources; competency, where it is appraised if the know-how to successfully implement the BIM Use is available; experience, where it is acknowledged if the responsible party has performed the BIM Use in the past.

After this consideration the team should evaluate the potential value gained, as well as the additional project risk that may be incurred by implementing the BIM Use. Finally, it is necessary to decide if the BIM Use should be implemented, and to do so it is required that the potential added value or benefit to the project of each use is compared to the cost and risk associated. After all factors are considered the team must then decide each BIM Use is implemented or not.

2.2.1.2- Design of BIM Project Execution Process

After each BIM Use is identified, it is necessary to understand the implementation process for each use and for the project as a whole. This chapter describes a procedure to design the BIM Project Execution Process. The process map developed in this chapter allows the team to understand the overall BIM process, identify the information exchanges that will be shared between multiple parties, and define the various processes to be performed for the identified BIM Uses. To design the BIM project execution process this guide suggests mapping the BIM process for the project by developing an overview map, which shows the different BIM Uses performed, and then developing detailed BIM Use process maps to define the specific BIM implementation at an increased level of detail.

The first step in creating a BIM overview map is to put the identified potential BIM Uses into the map as processes, considering that the same use can be performed several times, being possible to add it in the map at different places. The purpose of the overview map is not only identify the phase for each BIM Use but also provide the team with the implementation sequence (when the processes originated from BIM Uses are established, the team should sequentially order them). When the sequence is complete the responsible parties should be identified for each process, being responsible for defining the information required to implement the process as well as the information produced by the process. The guide suggests that each process within the BIM overview map should include a process name, project phase, the responsible party and the title of the detailed map that indicates the process.

The last step in creating the BIM overview map is to define the information exchanges required to implement each BIM Use. These are either internal to a particular process or shared between processes and responsible parties. These exchanges are typically implemented through the transfer of a data file, although it could also include the input of information into a common database. After creating and overview map, it is necessary to create a detailed BIM Use process map for each identified BIM Use, so that the sequence of the processes to be performed within that use is defined. The detailed map includes three categories of information: the reference information, which is structured information resources required to execute a BIM Use; the process, which is a logical sequence of activities that constitute a particular BIM Use; and the information exchange, which is the BIM deliverables from one process that may be required as a resource for future processes

The first step in creating a detailed process map is to identify the core processes of the BIM Use, and place them in sequential order. After the dependencies between the processes are defined, the team must identify the predecessors and successors for each process and define their connection. The next step is to develop the detailed process map with: the reference information by identifying the informational resources needed to accomplish the BIM Use; the information exchanges by defining all the exchanges; the identification of the responsible parties for each process.

After the detailed process map is developed it is necessary to add goal verification gateways at important decision points in the process. These provide the opportunity for the project team to represent any decisions, iterations or quality control checks required before the completion of a BIM task, being used to ensure that the results or deliverables of a process are met. Taking into account that this map can be used for other projects it should be saved and reviewed at numerous times throughout the BIM implementation process. The maps should be periodically updated and after the completion of the project it may be helpful to compare the actual process used with the planned process.

2.2.1.3- Develop Information Exchanges

This guide provides and Information Exchange Worksheet that should be completed in the early stages of a project, after designing and mapping the BIM process. The goal of the worksheet is to assist the team by providing a method for defining information exchanges between processes. After the process map development and information exchanges between project participants are identified, it is important for the team members, and, in particular, the author and receiver of the information exchange transaction to clearly understand the information content.

The first step to create the information exchange requirements is to define the shared information exchanges between two parties, being that one BIM Use may or may not have multiple exchanges. The time of exchange should be derived from the Level One map to ensure that the involved parties know when the BIM deliverables are expected to be completed along the project's schedule. After the information exchanges are established the team must select an element breakdown structure for the project, and then identify the information requirements for each exchange. To do so the following information should be documented: the model receiver, which identifies all the project members that will receive the information, these are responsible for filling the input exchanges; the model file type, that specifies the software applications used during each BIM Use by the receiver, this can be useful to prevent any lack of compatibility between exchanges; information, where it is identified the data needed for the implementation of the BIM Use; Notes, where all the necessary content that was not specified in the other points can be described.

It is important to assign responsible parties to author the information in each line item in an information exchange, and additionally the time of input should be when it is needed by the model receiver. Once the information requirements are defined it is necessary to compare the input information (requested) with the output information (Authored), to find possible inconsistencies and mismatches. When this occurs there is a need for a remedial action, which can be to revise the information to a higher level of accuracy and/or include addition information or revise the responsible party so that information is authored by the organization performing the BIM Use.

2.2.1.4- Define Supporting Infrastructure for BIM Implementation

The final part of the BIM Project Execution Planning Procedure is to identify and define the project infrastructure required to effectively implement BIM as planned. In a way of facilitating the visualization of the infrastructures they are presented at Table 2.6, with their main goals and objectives.

Table 2.6- Supporting infrastructure for BIM implementation (CIC, 2011)

BIM Project Execution Plan Overview	Define the BIM mission statement and other executive summary level information. Also establish the importance of the plan.
Project Information	Review and document critical project information that may be valuable for the BIM team for current and future reference. This section includes basic Project information that may be valuable for current and future.
Key Project Contacts	Identify at least one representative from each stakeholder involved, including the owner, designers, consultants, prime contractors, subcontractors, manufacturers, and suppliers. All stakeholders' contact information should be collected and exchanged.
Project BIM Goals / BIM Uses	It is valuable for the team to document the reason for implementing BIM on the project and explain why key BIM Use decisions were made. Document the BIM goals, the BIM Use Analysis Worksheet, as well as specific information on the BIM Uses selected.
Organizational Roles and Staffing	The roles in each organization and their specific responsibilities must be defined. Identify which organizations will staff and perform each BIM Use selected.
BIM Process Design	Document the process maps created for each selected BIM Use, including the overview map of the BIM Uses, a detailed map of each BIM Use, and a description of elements on each map.
BIM Information Exchanges	Document the information exchanges created as part of the planning process in the BIM Project Execution Plan.
BIM and Facility Data Requirements	Document the BIM requirements in the native format from the owner in a way that the team is aware of the requirements and can plan accordingly to deliver those requirements
Collaboration Procedures	Define the collaboration strategy where it is documented how the team is going to collaborate in general and the specific collaboration activities.
	Determine the schedule for information exchange between parties and analyze the information exchanges. Document them all in one place.
	Determine the physical environment needed throughout the lifecycle of the project to accommodate the necessary collaboration, communication, and reviews that will improve the BIM Plan decision making process.
	Establish communication protocol with all project team members. Define and resolve the document management.
Quality Control	Determine and document the overall strategy for quality control of the model. To ensure model quality in every project phase and before information exchanges, procedures must be defined and implemented.
	Each team member should perform quality control checks of their design, dataset and model properties before submitting the deliverables.
Technology Infrastructure Needs	Determine the requirements for hardware, software platforms, software licenses, networks, and modeling content for the project.
Model Structure	Determine how the model is created, organized, communicated and controlled.
Project Deliverables	Consider all the specific information about the deliverables required by the project owner.
Delivery Strategy / Contract	Define Project Delivery Approach.
	Define criteria and procedure for the selection of future project team members based on their organization's BIM ability.
	Define BIM Contractual Language.

2.2.2- AEC (UK) BIM Protocol Project BIM Execution Plan

The AEC BIM Protocol is the attempt to implement UK BIM standards for the Architectural, Engineering and Construction industry. The Table 2.7 represents the main points of this protocol.

Table 2.7- Main points of AEC (UK) BIM Protocol Project BIM Execution Plan

AEC (UK) BIM Protocol Project BIM Execution Plan
Execution Plan Checklist/ Guidance
Project Information
Project Objectives and Goals
Collaborative Working
Project Resources and IT Requirements

The protocol starts with a checklist with headings that have been used to form the basis of a project BIM Execution Plan. Then, in the Execution Plan Guidance there is a description of how to fill the subtitles existent on the main headings.

2.2.2.1- Project Information

The project information begins with the project description where it is recommended to briefly describe the project in terms of: project owner; project name; project type; and geographic location. After the project description is completed it is necessary to define the project scope. To do so it is necessary to describe the: project phasing; approximate site area; approximate gross internal floor area; and contract / delivery type.

The next step is to identify any unique project conditions / challenges which may influence the approach to the project design / delivery. Finally, it is necessary to record all key project stakeholder details as the company role, name and contact, and record the key building information modeling personnel responsible for each discipline.

2.2.2.2- Project Objectives and Goals

After the project information is completed it is necessary to define the project objectives and goals. The BIM execution plan should document the overall Project BIM objectives. These should be discussed and agreed between all stakeholders. Sometimes, besides the agreed Project BIM objectives, the stakeholders will have their own BIM objectives, which should be documented to help promote a better understanding of individual stakeholders to BIM.

Taking into account that the Project BIM objectives and goals will change in accordance with various phases of project development, the programming of the agreed Project BIM objectives must be taken into consideration and agreed between all stakeholders, and then it should be documented. To assist in the exchange and delivery of collaborative BIM data it is recommended that the stakeholders collectively develop and agree a level of development matrix, to facilitate the planning and communication of the collective BIM deliverables. Finally, it is recommended by the protocol that the performance of the project delivery is quantified, in order to incorporate some key performance indicators to assess it periodically.

2.2.2.3- Collaborative Working

To do an effective collaborative working the protocol suggests that there should be established and agreed common BIM standards between all project stakeholders. Establishing agreed project coordinates, like a referenced origin point and common modeling standards is also essential to a good collaborative working. Efficient and regular communication, is essential to the collaborative work as the protocol encourage regular BIM project meetings with the necessary frequency. In addition there should be considered a possible co-location for the project stakeholders to improve the communication.

The regular exchange of BIM data is an essential part of a successful BIM project. All Stakeholders should establish agreed Project Data Exchange Protocols, and should have in place suitable procedures, and documentation confirming their existence, for Model Data validation for both issuing and receiving BIM data. Also, and due to BIM projects often requiring segregation of data into convenient sized pieces, it is essential a description and a diagram of how the project data will be subdivided.

As part of planning BIM data exchange methodologies it may be useful to test the exchange workflows prior to using them on the real projects. This procedure can reduce the risk of problems later and establish the most efficient way of collaboratively exchange information. Due to the existence of different stakeholders it is prudent to establish common modeling units, and agreed methods for area calculations.

2.2.2.4- Project Resources and IT Requirements

In order to finish the project with the desired quality it is necessary that stakeholder´s BIM software skills and experience match the required BIM deliverables. If there is any type of incapability all the stakeholders must reach to an appropriate course of action to be taken. BIM deliverables often have their own inherent hardware/technology infrastructure requirements, so it is essential to understand these and ensure that the project stakeholders can meet them. Besides that, it should exist a special attention to the compatibility of all stakeholders´ software, any known incompatibilities should be acknowledge and documented. The exchange of information between all stakeholders is of great importance, being essential to establish a common data environment at the earliest opportunity.

Finally, it is important to recognize the specific BIM content like detailed manufacturer data or bespoke project content. The protocol recommends that in the absence of pre-configured BIM content there should be allocated resources to the creation of a suitable content library. Also consideration should be given to the variety of requirements of the BIM content and the differing stages of a project.

2.3- Project management

Project management has its own definition depending of the organization concept. Two of the most reputable associations, PMI and APM, have created their frameworks and set of good practices and defined project management on its own terms. APM defines project management as the methodology to do the planning, organization, monitoring and control of all aspects of a project including the motivation of all involved to achieve the project objectives safely and within agreed time, cost and performance criteria. The project manager is the single point of responsibility for achieving this.

PMI created the PMBOK, which defines Project management as the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. Project management is accomplished through the appropriate application and integration of the 47 logically grouped project management processes, which are categorized into five Process Groups. In addition to the PMBOK and APM there are also programs such as PRINCE2 that use the project management practices. Structured approaches to project management as in PMBOK or APM, and products such as PRINCE2, allows to capture all elements of the project upfront, educate project team on the various elements and their relationships /dependencies, to create a workable and accountable team environment (Essays UK, 2013).

PRINCE2 is a structured, but flexible, process-based project management standard to improve the effectiveness of project management (Ghosh et al. 2012). According to the official PRINCE2 website, this management methodology developed in the UK includes six variables: costs, timescales, quality, scope, risk, and benefits. PRINCE2 emphasizes key risks on a project, being that PMBOK is more comprehensive (Siegelaub, 2004). Therefore it is strong on risk management, but some areas as leadership and people management skills, detailed coverage of project management tools and techniques covered by other existing and proven methods are excluded from PRINCE2 (Essays UK, 2013).

Unlike PRINCE2, the APM body of knowledge and PMBOK are collections of project management knowledge, providing introductions and common guides to those areas considered essential to handle projects, and managing projects. They differ from PRINCE2 as they take more descriptions and explanations to the project management topics, taking a discipline based approach, while PRINCE2 take a more process based approach to project management.

APMBOK includes ideas and knowledge that may only apply to some projects, being a "more inclusive" approach to project management knowledge. The main differences between PMBOK and APMBOK are that: while APMBOK covers its wider range of topics at a lower level of detail with the assumption that detailed descriptions and methods can be found elsewhere (Morris, 2004), defining the competencies that should be understood but not necessarily the steps that should be taken, PMBOK is more process based, defining the processes that a project manager should follow to execute a project; PMBOK focus more on the management of single projects, instead of APMIK which have sections for program and portfolio management (Ghosh et al. 2012).

Therefore, comparing the three ways of approaching project managing, the best to use in a BIM-based project is the PMBOK. It is better detailed than the other two, including more areas, and with better explanations of how to reach a proposed goal, with well-defined processes.

2.3.1- Project management by the PMBOK perspective

Project management should follow a systematic process. PMI breaks project management into process groups and knowledge areas. The knowledge areas are integration, scope, time, cost, quality, human resource, communications, risk, procurement, and stakeholder management. The process groups are initiating, planning, executing, monitoring and controlling, and closing.

The project is officially approved in the "initiating" phase, where it is obtained authorization to start a new project or phase. Once the project has been approved, it moves from initiating into planning, where it is created the plan for how the planning will be done and how to execute, monitor and control, and close the project.

The execution phase is where the team completes the work according to the procedures and processes detailed in the planning phase. While this phase is in progress, the work results are fed into monitoring and controlling, in a way that certificates that the project is tracking to the baselines of the plan. If there are changes made in the plan it is necessary to evaluate them to determine their impact, identify the best measures to deal with them, and decide their possible approval. Approved changes that don't affect the baseline are fed back into executing to be implemented. For changes that require an adjustment to the baseline, a replacing effort must be completed before they are executed. When the project is terminated, the project moves to closing.

2.3.2- Knowledge areas

The project management processes are grouped into the Knowledge Areas, the project teams should use all the Knowledge Areas appropriated for their projects. A Knowledge Area represents a complete set of concepts, terms, and activities that make up a professional field, project management field, or area of specialization (Project Management Institute, 2013). Taking into account that the project management processes are not independent of each other, the integration is about balancing all the Knowledge Areas throughout the life cycle of the project. Project Integration Management includes the processes and activities to identify, define, combine, unify and coordinate the various processes and project management activities within the project Management Process Groups (PMI, 2013).

The work of the project is a concern of the Project Scope Management, which includes all the processes involved with the work, and only with the work required, to complete the project. It intends to elucidate the needs, establish the expectation, deliverables, manage changes and reduce surprises. In addition, and being that every project has a deadline and it is anticipated to be accomplished until the defined timeline, it is important to keep the project activities on track and assure the completion of the project on time. The Project Time Management helps in this task by handling with the estimation of the duration of the project plan activities, conceiving a project schedule, and monitoring and controlling possible deviation from it.

Accompanied to the deadline, usually also comes an approved budget. The Project Cost Management Area of Knowledge is necessary to assess, allocate and administer costs and resources, and to keep track of them ensuring that the project is within the approved budget. Besides fulfilling all the time and cost specifications, it is vital to guarantee that the project requirements, including product requirements are met and validated. The Project Quality Management includes the processes and activities of the organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the proposed needs. These processes also measure overall performance, and monitor project results and compare them to the quality standards defined.

Being that every project has its team, it is essential a Project Human Resource Management to include on the project all aspects of people management and personal interaction including leading, coaching and dealing with conflicts. The people with assigned roles and responsibilities constitute the project team. Each team is different and requires the use of different communication styles, leadership skills, and team-building skills in a way that they give their best contribution to the project, and therefore it is essential to plan how the human resources are going to be managed on the project.

Most of the time of a project manager is spent communicating, so one of the most important Area of Knowledge is the Project Communications Management, as it requires a complete comprehension of the project and allows project managers to better share and distribute the information with the team members and the project stakeholders. The existent processes of the communications management ensure that all project information including plans, risk assessments, meeting notes, and more are collected and documented.

Being that no project exists without risk, as there may be all sorts of events that can have negative influence the project. To decrease at a minimum, the likelihood of those events and mitigate their impacts, the Project Risk Management is concerned with identifying, controlling and response planning for potential risks that may impact the project.

In order to meet the demands of project scope, sometimes it is necessary to purchase or acquire products, services or results from outside the project team. The Project Procurement Management includes the processes necessary to fulfill that necessity, including the processes to help create, read and manage contracts. In addition, a project usually has different people, groups interested or that are going to be impacted by its deliverables or outputs. Project Stakeholder Management includes the processes required to identify who impact or is impacted by the project, and decide the best way to make a continuous communication with the stakeholders, in order to understand their needs and expectations, always ensure that the stakeholders are on current of issues as they occur and guarantee that the team is able to manage conflicting interests and engage the stakeholders on the project decisions and execution.

2.3.3- PMBOK processes

There are 47 processes grouped at the knowledge Areas. These processes are mapped at Table 2.8 and grouped in their respective project phase. Furthermore at the “Annex 1” it is given a more structured and detailed look to the presented processes, describing step by step how to complete the PMBOK processes, based on the methodology of the PMP Exam Prep (Mulcahy, 2013).

Table 2.8- PMBOK Knowledge Areas and processes (PMI, 2013)

Knowledge Areas	Project Management Process Groups				
	Initiating Process Group	Planning Process Group	Executing Process Group	Monitoring and Controlling Process Group	Closing Process Group
Project Integration Management	Develop Project Charter	Develop Project Management Plan	Direct and Manage Project Work	Monitor and Control Project Work Perform Integrated Change Control	Close Project or Phase
Project Scope Management		Plan Scope Management Collect Requirements Define Scope Create WBS		Validate Scope Control Scope	
Project Time Management		Plan Schedule Management Define Activities Sequence Activities Estimate Activity Resources Estimate Activity Durations Develop Schedule		Control Schedule	
Project Cost Management		Plan Cost Management Estimate Costs Determine Budget		Control Costs	
Project Quality Management		Plan Quality Management	Perform Quality Assurance	Control Quality	
Project Human Resource Management		Plan Human Resource Management	Acquire Project Team Develop Project Team Manage Project Team		
Project Communications Management		Plan Communications Management	Manage Communications	Control Communications	
Project Risk Management		Plan Risk Management Identify Risks Perform Qualitative Risk Analysis Perform Quantitative Risk Analysis Plan Risk Responses		Control Risks	
Project Procurement Management		Plan Procurement Management	Conduct Procurements	Control Procurements	Close Procurements
Project Stakeholder Management	Identify Stakeholders	Plan Stakeholder Management	Manage Stakeholder Engagement	Control Stakeholder Engagement	

3- Comparison between BIM Execution Plan and Project Management Body of Knowledge

Although the topic of BIM has been studied by academics, professionals and software vendors, there is still a shortage of project management literature focusing on BIM from the project management point of view (Bryde et al., 2013). An exception to that is the Code of Practice for Project Management for Construction and Development, which addresses some practices that project management in the construction business should take already focusing on BIM. Another exception is Allison (2010), who addresses the BIM potential as a PM tool directly, describing 10 reasons why project manager should champion 5D BIM. These advantages are resumed at Table 3.1.

Table 3.1- 10 Reasons Why Project Managers Should Champion 5D BIM (adapted from Allison, 2010)

Benefit for project management	Reason
PMs help organize the project schedule and budget during preconstruction	An integrated 5D BIM model immediately updates both the schedule and budget when any design change occurs
The Project Manager needs to work well with the Design Team to help keep the project on track	By using the integrated 5D BIM model to visualize and explore the impact of changes, the project manager can keep project scope in check and become a trustworthy liaison between the designers and Owner
Hiring and controlling the Subcontractors	Having a handle on clash detection and coordination plays a key role in keeping Subs' work predictable
Request for information and change orders	By starting the coordination process much earlier using Coordination Resolution, the RFIs and change orders can be brought no near zero
Give PMs a project dashboard instead of a rear view mirror	By continually monitoring Sub contractors performance the PM can automatically get a two week look-ahead schedule that give alarms when a crew late start or delay is likely
Optimize the Owner's experience and satisfaction	There is no greater influence on satisfaction than a project delivered on time and on budget
Project closeout, including operations and maintenance	New reporting capabilities and light-weight model presentation modes allow the PM to present a 6D BIM – a facilities resource with information on warranties, specifications, maintenance schedules, and other valuable information
Profit margin	By thoroughly understanding the project in 5D, the PM has more tools at his disposal to keep tight reins, and more reports to monitor progress
Progressive Owners are mandating BIM on their projects	Becoming the BIM expert, in both preconstruction and out in the field, makes the PM invaluable and a key player
The project's success with 5D BIM means the opportunity to grow the firm's reputation and helps the corporate team win new business.	The project's success with 5D BIM means the opportunity to grow the firm's reputation and helps the corporate team win new business

Also it is starting to be noticed the interest on BIM by analyzing the new PM frameworks, such as IPD, which increases the need for closer collaboration and more effective communication (Eastman et al., 2011). When people collaborate on a project, communicating specific characteristics of the project amongst the different parties involved requires documentation of these characteristics (Lee, 2008). By taking the documentation to a virtual environment, BIM allows a level of coordination of complex projects that exceeds the traditional projects.

By using BIM, the communication process, which exists between stakeholders on a project, can be enhanced strikingly, allowing to project managers to reengineer the processes to better integrate the different stakeholders involved in modern construction projects (Bryde et al., 2013).

In a way that a further comparison of BIM and project management is possible and for the purpose of this work it is going to be made a comparison between the Building Information Modeling Project Execution Planning Guide (CIC, 2011) and the processes and areas of knowledge of project management defined at PMBOK.

3.1- Integration Management

At Table 3.2 it is made the comparison between the integration management processes as described by the PMI with the analyzed BEP, from Penn University. In addition, it is discussed the common and uncommon points and what can be added to improve BEP.

Table 3.2- Comparison of Integration Management in PMI and BEP

<table>
<tr><th>PMI</th><th>BEP</th></tr>
<tr><td>Develop Project Charter;
Develop Project Management Plan;
Direct and Manage Project Work;
Monitor and Control Project Work;
Perform Integrated Change Control;
Close Project or Phase.</td><td>There are some points to integrate the organizations, like the statement of the BIM mission, and the BIM plan overview;
It is given a great importance to the coordination and integration between all the models and stakeholders within the project.</td></tr>
<tr><th colspan="2">Discussion</th></tr>
<tr><td colspan="2">Although there are some points that integrate the organizations, it can make sense to develop some procedures, like determining the companies’ culture and existent systems or to uncover the initial assumption, agreements and constraints. In addition, the BEP is lacking a plan of how to deal with changes and how to approve and implement them.</td></tr>
</table>

3.2- Scope management

At Table 3.3 it is made the discussion between BEP and PMBOK concerning the processes of scope management area. There are also exposed the opportunities of improvement of the BEP based on the project management best practices.

Table 3.3- Comparison of Scope Management in PMI and BEP

<table>
<tr><th>PMI</th><th>BEP</th></tr>
<tr><td>Plan Scope Management;
Collect Requirements;
Define Scope;
Create WBS;
Validate Scope;
Control Scope.</td><td>Definition of the BIM mission statement and other executive summary level information;
Consideration of all the specific information about the deliverables required by the project owner;
Consideration of all the specific information about the requirements required by the project owner and the other stakeholders;
Definition of the BIM Goals for the Project;
Definition of the Project Delivery Approach;
There should be decided if the BIM Use is implemented or not;
To facilitate the information exchanges there should be created a work breakdown structure to the building elements to better uncover the level of development of each building element.</td></tr>
<tr><th colspan="2">Discussion</th></tr>
<tr><td colspan="2">Although the scope is well defined by stating the BIM mission and by defining the BIM goals, which can act like the objectives of the project, there should exist a definition to access if the project is a success or not.
Then, by deciding if each BIM Use is going to be implemented, the scope is validated and the plan approved.
The requirements of the stakeholders and the deliverables required are a concern, however, there should exist a better development of how they should be created, organized, and registered.
Although the scope is defined, there should exist some control points and measures to know if the scope and goals are being followed or not and if they are really adapted to the reality of the project.</td></tr>
</table>

3.3- Time Management

At Table 3.4 it is made the comparison between the processes of time management area as described by the PMI with the analyzed BEP. It is also made a discussion of the common and uncommon points and what can be added to improve BEP.

Table 3.4- Comparison of Time Management in PMI and BEP

<table>
<tr><th>PMI</th><th>BEP</th></tr>
<tr><td>Plan Schedule Management;
Define Activities;
Sequence Activities;
Estimate Activity Resources;
Estimate Activity Durations;
Develop Schedule;
Control Schedule.</td><td>Description of BIM Uses;
There is a description of the resources and activities necessary to implement each BIM Use (BIM detailed map and BIM Use selection worksheet);
Organization of the BIM Uses according to project sequence (BIM overview Map);
Determination of the schedule for information exchange between parties and analyze the information exchanges;
On the project Information there should exist a category with the project schedule/phases/milestones.</td></tr>
<tr><th colspan="2">Discussion</th></tr>
<tr><td colspan="2">It is essential to define and order the BIM Uses (processes) and their needed resources, which will give to the project the order of implementation. In addition to the BIM detailed map, the activities necessary to implement each BIM Use and their sequence are defined. It is recommended to determine a schedule for information exchanges necessary to implement the BIM Uses and to document all the important timeline information, including the project milestones and their duration, being that these procedures are according with the project management best practices.
Although defining the project milestones give to the project some control, there should exist more information about when the project owner should be informed and how to deal with delays, which will give a better control of the schedule.</td></tr>
</table>

3.4- Cost Management

At Table 3.5 it is exposed the comparison made between BEP and PMBOK concerning the cost management processes area. In addition, it is discussed what can be improved on BEP taking into account the project management best practices.

Table 3.5-Comparison of Cost Management in PMI and BEP

PMI	BEP
Plan Cost Management; Estimate Costs; Determine Budget; Control Costs;	The only existent information about estimating cost is the BIM Use "Cost Estimation".
Discussion	
Cost Management is not a concern in BEP, providing only a BIM Use, that if decided can be applied. Taking into account that BEP is just a plan, it doesn´t make sense to discuss costs of the construction yet. Although it can make sense to attribute a cost to the project by estimating the number of hours necessary to implement each BIM Use and by attributing a cost to the team hours.	

3.5- Quality Management

At Table 3.6 it is discussed the processes of the quality management area of BEP and PMBOK. It is also exposed the opportunities of improvement of the BEP based on the project management best practices.

Table 3.6- Comparison of Quality Management in PMI and BEP

PMI	BEP
Plan Quality Management; Perform Quality Assurance; Control Quality.	It should be documented the overall strategy for quality control of the model. To ensure model quality in every project phase and before information exchanges, procedures must be defined and implemented; Each team member should perform quality control checks of their design, dataset and model properties before submitting the deliverables; Quality control of deliverables must to be accomplished at each major BIM activity.
Discussion	
There is a description of how the deliverables should be controlled and by whom, with some examples of quality checks that should be considered. In addition, it is indicated the time of the quality controls but there isn’t any type of plan to deal with nonconformities, which are a part of every project. In general BEP only concerns the quality of the BIM files and, although there is an indication of which checks should be done and the admitted tolerances for the models, a better development of the types of files that need to be controlled should be done, for example by creating checklists. The BEP should contemplate some points of how to control the system quality and not only the BIM files, which could be done for example by defining some key performance indicators. This will help the team to know if there are processes that need to be improved or to better define the admitted tolerances of the project system.	

3.6- Human Resource Management

At Table 3.7 it is compared the project management best practices and the BEP, concerning the human resource management area. This comparison is discussed and unveiled opportunities for improvement of the BEP based on the PMBOK processes.

Table 3.7-Comparison of Human Resource Management in PMI and BEP

<table>
<tr><th>PMI</th><th>BEP</th></tr>
<tr><td>Plan Human Resource Management;
Acquire Project Team;
Develop Project Team;
Manage Project Team;</td><td>Definition of the roles in each organization and their specific responsibilities;
For each BIM Use there is an identification of which organization(s) will perform that use;
Rating of the capabilities of each party for each BIM Use identified in the categories of Resources, Competency, Experience;
Identification of the responsible parties for each process.</td></tr>
<tr><td colspan="2">Discussion</td></tr>
<tr><td colspan="2">The greater concern is how to manage the human resources, instead of acquiring new team members. There are processes to identify and define project roles, responsibilities and the existing relationships.
The choice at the BEP is to rate the capabilities of the team on each BIM Use and then decide to use it, instead of developing the team to meet the demands. It should exist at this phase a plan of how to develop the project members if necessary, in order to achieve the full potential of the BIM project.
It doesn't make sense to define at BEP procedures to acquire new teams as for that it should exist a procurement guide prior to the development of the plan, being that this guide is a concern of each project´s organization.</td></tr>
</table>

3.7- Risk Management

At Table 3.8 it is compared the processes of the risk management area as described by the PMI with the analyzed BEP. The common and uncommon points of the risk management area are also discussed.

Table 3.8-Comparison of Risk Management in PMI and BEP

<table>
<tr><th>PMI</th><th>BEP</th></tr>
<tr><td>Plan Risk Management;
Identify Risks;
Perform Qualitative Risk Analysis;
Perform Quantitative Risk Analysis;
Plan Risk Responses;
Control Risks.</td><td>There is an identification of the additional value and risk associated with the implementation of each BIM Use (BIM Use selection worksheet).</td></tr>
<tr><td colspan="2">Discussion</td></tr>
<tr><td colspan="2">Although there is at the BIM Use selection worksheet a section where the team has the opportunity to identify the risks associated with each BIM Use, there is no identification at the BEP of the risks of the project, and taking into account that every project has its risks, there should be more guidelines at this point of how to analyze the risks and how the team should respond to them, including a more quantitative way of assessing the risks that each BIM Use helps mitigating.</td></tr>
</table>

3.8- Communications Management

At Table 3.9 it is compared the time management area as described by the PMI with the analyzed BEP. It is also discussed the common and uncommon points and possible improvements to BEP.

Table 3.9-Comparison of Communication Management in PMI and BEP

PMI	BEP
Plan Communications Management; Manage Communications; Control Communications.	Definition of the BIM Contractual Language; Quantification of the Information Exchanges required to implement each BIM Use documenting the model receiver, model file type, type of information and notes; A comparison between the authored and requested information should be completed; Existence of preferred notation, the Business Process Modeling Notation (BPMN); It should be documented how the project team will collaborate in general and the communication protocol; Definition of how the documents are going to be managed; Quantification of the physical environment needed throughout the lifecycle of the project to accommodate the necessary collaboration, communication, and reviews that will improve the BIM Plan decision making process.
Discussion	
This is the most developed area in the BEP. There is plan of how to manage an appropriate communication by defining all the notations, the BIM contractual language, and by defining a communication protocol and how the collaboration is done. There is also a process to define and control the information exchanges, its requirements and who is receiving and sending it and how. Processes and methods to control the communications also exist, as comparing the authored information with the requested and defining responsible parties to each line item in an information exchange. Although this area is well developed according with the processes of the communication management area, it can be improved by developing a responsibility assignment matrix (for example a RACI matrix) for each activity necessary to implement each BIM Use and by defining a common data environment for the BIM implementation.	

3.9- Procurement Management

At Table 3.10 the BEP and PMBOK are discussed concerning the processes of the procurement management. The opportunities of improvement of the BEP based on the project management best practices are also exposed.

Table 3.10-Comparison of Procurement Management in PMI and BEP

PMI	BEP
Plan Procurement Management; Conduct Procurements; Control Procurements; Close Procurements.	The BEP only mentions that the procurement is a main decision, when deciding about the project delivery approach.
Discussion	
At BEP there is almost no information about procurement, which make sense as the BEP is a plan to implement BIM on a project. Procurement should be analyzed at a procurement guide before the BEP is created, and they should be the concern of each project organization.	

3.10- Stakeholder Management

At Table 3.11 it is exposed the comparison between BEP and PMBOK concerning the stakeholder management processes area. In addition, it is discussed what can be improved on BEP taking into account the project management best practices.

Table 3.11-Comparison of Stakeholder Management in PMI and BEP

PMI	BEP
Identify Stakeholders; Plan Stakeholder Management; Manage Stakeholder Engagement; Control Stakeholder Engagement.	Identification of at least one representative from each stakeholder involved; All stakeholders' contact information should be collected and exchanged; The BIM Use Selection Worksheet should be completed with key project stakeholders.
Discussion	
Stakeholders are identified as well as their requirements and representatives. The contact information is exchanged simplifying communication and working in a collaborative manner. Although there is an indication that the reunions and phases should be completed with the stakeholders to better engage them, there is almost no information about mapping and controlling the stakeholders' engagement, and how to create plans and strategies to allow that. This should be improved in order to enhance the project communication and integration.	

4- BIM Execution Plan improvement based on Project Management Best Practices

In this chapter it is proposed a BIM Execution Plan guide configured to assist the implementation of a BIM project that includes project management best practices. This BEP guide enables the project team to develop a BIM implementation strategy, by addressing the necessary BIM Uses to deliver throughout the project and by helping the project team to deal with the different areas related to project management. The BIM execution plan described throughout this chapter presents an implementation guide comprised of 12 categories of information:

1. **Overview and scope of the project:** Documents the reason for implementing BIM as well as its requirements, analyzing the characteristics of the project as the project success criteria and the scope of the project;
2. **Project information:** Compiles the project basic information, such as the project description, the schedule of the project, the cost plan, and the risks involved for future reference;
3. **Stakeholders' information:** Includes the stakeholders' identification, with their respective contacts and organizations. In addition, it proposes a method to manage the stakeholders to take the best possible influence of them;
4. **Project goals/BIM Uses:** Presents a procedure to analyze the characteristics of the project, define and prioritize the main project goals and subsequently obtain the potential BIM Uses assigned to achieve the project objectives. This stage also proposes a method to select the BIM Uses from the potential delimited;
5. **BIM positions, responsibilities and training actions:** Defines the BIM main positions in a way that there are no uncertainties of the team members and responsibilities, as well as the needed training actions to effectively implement BIM. In addition, this stage documents which organizations will perform each BIM Use and model and identifies the necessary staff to successfully implement the plan;
6. **BIM process mapping:** Documents and proposes a method to illustrate the execution process, by representing through the use of process maps the workflow and interactions between the BIM Uses. It also documents the more detailed process maps with the activities necessary to implement a BIM Use, as well as the responsible stakeholders for their implementation;
7. **Information exchanges requirements:** Expresses the information exchanges that need to occur throughout the project, being defined the methodology to determine the minimum information requirements for each BIM Use;

8. **Collaboration procedures:** Documents the electronic and collaboration activity procedures. It includes how it will be established the common data environment, the meeting schedules and agendas, and the model management procedures as the file permissions and access rights;
9. **Quality management:** Presents a methodology to ensure the quality of the BIM system, files and models. In addition, it contains a procedure to deal with nonconformities and changes to the project;
10. **Technological infrastructures:** Defines the hardware and software infrastructures needed to implement the BIM Uses;
11. **Model Structure:** Documents the model structure, being that it is the phase where the folder structure, file naming convention, coordinate system, and modeling standards are defined;
12. **Project deliverables:** Documents the expected BIM deliverables from the project.

These steps are introduced in the following sections, where there are chapters dedicated to explaining the details related to each step of the BEP.

4.1- Overview and scope of the project

When initiating the BIM Execution Plan the leading team should integrate the organizations involved on the project, defining their methods and ways of work as well as the BIM objectives and project initial requirements. At this phase of the BEP it should be documented the product scope description, the acceptance criteria, the project exclusion, constraints, and assumptions as the PMBOK suggests. At the existent BEPs this topic already exist, however it is underdevelopment according with the project management best practices. Therefore, this guide will propose some additional points to be considered as the culture of the organizations involved and the project success criteria. In addition, it is going to be developed the BIM mission and scope of the project, the BIM requirements and installation information sections by giving more details of how it should be done according with PMBOK.

4.1.1- Culture of the organizations involved

The first step is to define the organization´s culture and existing systems that can influence the project throughout its life cycle so that the project team can adapt to different situations. The culture of the organizations can offer some constraints to the project and expose already existent assumptions.

An organization´s culture and style affect how it conducts projects (PMI, 2013). Some suggestions of topics to be analyzed by the project team are: the organization’s mission, values, beliefs, expectations, policies, methods, motivation and reward system, code of conduct, work ethic, work hours and view of leadership, hierarchy, and authority relationships.

4.1.2- BIM mission and scope of the project

After the organization´s culture is defined the team should establish the BIM mission statement and the scope of the project. The reasons to implement BIM should be clarified, such as gaining competitive advantage on proposals, increasing productivity, improving design quality, reacting to industry demand, satisfying owner requirements, or improving innovation (CIC, 2011) and how it will maximize the value of the project, by defining its mission and major proposed results (what the project aims to achieve and its importance). By defining these parameters the team acquires a better comprehension of the projects scope and sets the stage for future organizational decisions related to BIM by clarifying what it is going to be made and the reason why it is important.

4.1.3- Project success criteria

The criteria for measuring project success must be set out at the beginning of the project, otherwise different team members will find themselves working in differing directions and some might perceive the project to be a failure (Baccarini, 1999). There are two concepts in defining the project success: the first is the project management success which focuses upon the project process and in the accomplishment of cost, time, and quality objectives; the second refers to the product success which deals with the effects of the project´s final product (for example: reliability of the building). In order to properly define and assess project success, a distinction should be made between these two criteria (David Baccarini, 1999). This is important as a project can be managed successfully but may not meet the costumer or organizational expectations.

Both the project success criteria should meet the stakeholders´ satisfaction. The project management team must identify the stakeholders, and ascertain their needs and expectations to ensure a successful project (PMI, 2013).

4.1.4- BIM requirements and installation information

The team should collect the owner and stakeholders' needs and requirements for the BIM project, which may include requirements about quality, compliance, project management requests, about how the work is managed or capabilities that the stakeholders would like to see on the product. The process of defining the requirements gives a more detailed idea of what the stakeholders expect and assume of the project and, along with the project success criteria, provides the basis for the definition of the BIM goals as well as a better comprehension of the project scope. The requirements need to be measureable and testable, traceable, complete, consistent, and acceptable to key stakeholders (PMI, 2013).

The format of a requirements document can range from a simple document listing all the requirements categorized by stakeholder and priority, to more elaborate forms containing an executive summary, detailed descriptions, and Annexs (PMI, 2013). At this phase the team should make sure that the requirements can be met within the project objectives and capabilities, and if not try to adjust the competing demands of that requirement, making sure that there are not any conflicts between requirements.

In addition, the team should expose here possible agreements, initial assumptions, constraints, how to deal with the sustainability of the project, and other influences related to the project and how each will be managed or addressed within the project (PMI, 2013). These points can have implications on the scope of the project as well as on the project goals, milestones, cost limit, quality, resources or risk.

4.2- Project information

The second phase of the proposed BEP is the description of the project information for future reference throughout the building´s lifecycle, which is an integrated part of the project reference information from the key aspects of the BIM execution plan (Table 2.3). This chapter has already well developed points according with the PMBOK. Therefore, the general project information and the calendar of the project are based on the already existent BEPs, in spite of focusing on the control of this areas, by adding deadlines at which the stakeholders should be informed. Additionally, there are going to be added two sections related to cost plan and to the identification of the risks of the project, approaching the BEP to the PMBOK.

4.2.1- General project information

The team should start by documenting the general project information for future reference. At Table 4.1 there is a proposal of how the needed information based on the reviewed BEPs should be documented.

Table 4.1- Structure to register the general information for future reference

Project owner	(...)
Project name	(...)
Location/Address of the project	(...)
Project type	(...)
Contract type/delivery method	(...)
Project budget	(...)
Project description	General size, number of buildings, etc
Additional information	Unique project characteristics or requirements of the project

4.2.2- Calendar/ deadlines of the project

BIM implementation is time-sensitive. Processes, analysis, and deliverables can only add value to the project if information is available when needed (University construction management council, 2013). It should be identified the project phases/milestones as it is exemplified at Table 4.2. This identification is important as it provides the stakeholders and BIM leads the necessary information about the design deadlines, approvals, stages, key submittals and other key milestones of the project (University construction management council, 2013). This step allows sequencing the activities of the project and when possible it should be included the start and end dates for each milestones, in order to estimate the activities durations as it is recommended at PMBOK. There should be an indication whether the milestone is mandatory, such as those required by contract, or optional such as those based upon historical information (PMI, 2013).There is also a section to define the maximum deadline to which the project owner should be informed, this is important to define at the BIM execution plan as it allows a better future control of the schedule by giving a restricted deadline to deal with delays. The initial plan should be updated if dates are changed throughout the project.

Table 4.2- Structure to register the calendar of the project

Project phase/Milestones	Mandatory (Yes/ No)	Estimated start date (YYY-MM-DD)	Estimated end date (YYY-MM-DD)	Deadline at which the project owner should be informed, if work is not completed	Stakeholders involved
3D modelling- Volumetric study	No	2014-12-05	2015-12-05	2016-01-05	Architect, engineer
3D modelling- LOD 3	Yes	(…)	(…)	(…)	(…)
(…)					

4.2.3- Cost plan

The team should review and document a cost plan of the usage of BIM. This will allow a better control and a better perception of the costs of the project, the objective of the cost plan is to allocate the budget to the main elements of the project to provide a basis for cost control (Chartered Institute of Building, 2014). Taking into account that BEP is just a plan, the costs of construction can be difficult to predict at this phase, therefore the proposed cost plan is concerned with the project stage and it is calculated by attributing a cost to the estimated hours taken at a given phase of the project. Similar to the schedule there is also a cost limit to which the project owner should be informed, allowing the stakeholders to make a cost contention plan and decide which phases are critical to the budget. When the cost plan is in place, it serves as the reference point for the monitoring and control of costs throughout the project (Chartered Institute of Building, 2014). The proposed cost plan frame is exposed at Table 4.3.

Table 4.3- Structure to register the cost plan of the project

Project phase/Milestones	Estimated activity cost (activity hours * stakeholder time cost)	% of total budget	Cost limit at which the project owner should be informed	Stakeholders involved
3D Modelling	€	12	110% of the estimated cost	Architect, engineer
(...)				

4.2.4- Identification of the risks involved on the project

The next step is to analyze and document the existing risks on the project. A process of risk assessment and management has to be implemented at an early enough stage to have an impact on the decision-making during the development of the project (Chartered Institute of Building, 2014). Compared with many other industries, the construction industry is subject to more risks due to the unique features of construction activities, such as long period, complicated processes, abominable environment, financial intensity, and dynamic organization structures (Smith, 2003). Hence, taking effective risk management techniques to manage risks associated with variable construction activities has never been more important for the successful delivery of project (Wang et al., 2006).

At Table 4.4 it is exposed the table that the team should use to develop its risk management, similarly to PMBOK, which suggests that the risk management process has been divided into risk classification (description of the risk), risk analysis (probability and impact), risk response (mitigation measures) and risk control (responsible party and frequency of control.

Table 4.4- Structure to register the risks of the project

Description of the risk	Probability of occurrence (%)	Risk impact (1-5)			Risk Mitigation measures	Entity responsible for the risk management	Frequency of risk Review
		Time	Cost	Function			
Inadequate planning	20	4	4	5	Frequent revisions to BIM execution plan	Inadequate planning	20
(...)						(...)	

4.3- Stakeholders information

Every project can have stakeholders who are affected by or have an impact in the project in a positive or negative way (PMI, 2013). The main objective of this phase is to create methods to influence the stakeholders to have the best impact possible within their possibilities, taking into account that while some stakeholders have the power to influence the project, others are more limited. In order of doing it the team should find the best way of communicating with the stakeholders, to understand their expectations, managing conflicts and to be able to adopt the appropriate stakeholder engagement at each project phase and project decision.

Therefore, it is essential to identify (see section 4.3.1-), analyze, characterize, and find strategies to engage the different stakeholders that exist on the project (see section 4.3.2-). Although the identification of the stakeholders is already well developed and according with the project management best practices, it is added a chapter related to the stakeholders management in order to approach the BEP to the PMBOK.

4.3.1- BIM Leaders and Stakeholders identification

The team should identify at least one representative of each key stakeholder, which will be each discipline´s BIM point person(s) for the project. While the key stakeholders can be easy to identify as they are affected by the outcome of the project or have anyone in a decision-making role, the secondary stakeholders can usually be identified by interviewing the key stakeholders (PMI, 2013).

Choosing the appropriate BIM leads is critical to successfully implement BIM, and the team should identify them as early as possible, to better integrate their requirements and necessities, as late identifications often lead to delays as they will likely ask for changes (Mulcahy, 2013). The BIM lead should be a permanent part of the project team, and possess some skills of BIM to be capable of making key decisions about process and scope. The BIM leads must be committed to the project, to be able to provide the necessary support for the process.

All stakeholders' contact information should be collected, exchanged and, when convenient, posted on a shared collaborative project management web-portal (CIC, 2011). At this phase the information should be registered at Table 4.5, which includes each stakeholder´s name, organizational position, project role and contact information as the PMBOK and the analyzed BIM Execution Plans suggest.

Table 4.5- Structure to register the BIM leads and stakeholders of the project

Position	Organization	Contact name	Abbreviation	Location	Email	Phone
Architect	ABC	ABC	Arc	ABC	ABC	123
(...)						

4.3.2- Stakeholders management

Stakeholders should be classified according with their interest, influence, and involvement in the project, taking into consideration that the influence of a stakeholder may not occur or become evident until later stages of the project (PMI, 2013).

To assess the stakeholders´ influence they should be mapped. Stakeholder mapping is the process that identifies stakeholders and the associated expectations and power, as well as the way to manage the impact of the stakeholder effectively, so that they can be influenced to enhance their support and reduce their negative impacts. It also helps to understand any underlying political priorities within the stakeholders (Chartered Institute of Building, 2014). It analyses how much interested each stakeholder is in order to enforce its expectations on the project and if the stakeholders have the power to do so. At Figure 4.1 is displayed an example of how the stakeholders can be classified.

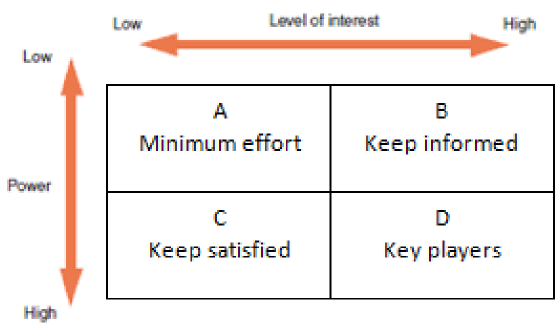


Figure 4.1- Stakeholders mapping (Chartered Institute of Building, 2014)

Besides mapping the stakeholders it is also important to analyze the stakeholders' engagement and how it is compared to the desired engagement for the project. Stakeholder engagement throughout the life cycle of the project is critical to project success (PMI, 2013). It is how it is accessed the proper method of managing the stakeholder according with the project needs. This guide proposes that the stakeholders' engagement is to be classified as the PMBOK suggests: Unaware if the stakeholder is unaware of project and potential impacts; Resistant if the stakeholder is aware of project and potential impacts and is resistant to change; Neutral if the stakeholder is aware of project yet it is neither supportive nor resistant; Supportive if the stakeholder is aware of project and potential impacts and is supportive to change; and Leading if the stakeholder is aware of project and potential impacts and is actively engaged in ensuring the project success. Not every stakeholder will be at the desired engagement level. Some will be less and some will be more engaged. Therefore, it is important to define the current and desired engagement level of each stakeholder and plan methods to change from the current to the desired level.

Table 4.6 demonstrates how it should be compared the current engagement classification of the stakeholder with the necessary for the project. At the stakeholder description it should be registered the stakeholder´s position at the power/interest matrix with possible notes, for example if the stakeholder has some specialty or area of special interest it should be specified. This could be helpful to find a method to manage the stakeholder, for example if a stakeholder is an expert at the risk areas the team can ask the stakeholder to participate in the risk management process to increase the engagement level. The team should analyze the gaps between the current and desired engagement level and determine the best option to manage the expectations of the stakeholders and fill the gaps.

Table 4.6- Structure to register the Stakeholders engagement level

Stakeholder	Stakeholder description	Current engagement level of the stakeholder	Desired engagement level	Method (s) of managing the stakeholder
Architect	Position C at the mapping matrix. Expert at risk area	Supportive	Leading	Incorporate the architect at the planning risk decision and keep him integrated on the project
Investor	Position D at the mapping matrix Supports with large funding the project, but exerts lots of pressure	Leading	Leading	Inform the investor of all major steps of the project, involving him at the project meetings and keeping him constantly informed about the deadlines and costs achievement
(...)				

4.4- Project Goals/BIM Uses

Once defined the project information and the necessary information about the project´s stakeholders the planning team should perform a detailed analysis of the project´s main goals and the necessary actions to achieve them with the appropriate BIM Uses. The identification of the project goals and BIM Uses is one of the key aspects identified and the foundation of BIM implementation and therefore of the BEP (University construction management council, 2013).

A BIM Use is a unique task or procedure on a project which can benefit from the integration of BIM into that process (CIC, 2011). The BIM Uses should be identified as early as possible, to be possible to create appropriate models for the uses. It is far easier to prepare for downstream use than it is to retrofit objects after the fact (University construction management council, 2013). This chapter of the BEP is one of the most important and very specific to BIM related projects, and as a result this chapter is going to be based on the existent BEPs, being a collection of the best features of each of them. However, it is going to be added a topic to the BIM goals control, in order of having a better scope control and therefore approaching to the recommended by the project management best practices.

4.4.1- Identification of the BIM Goals and possible BIM Uses

Before the identification of the BIM Uses, the planning team should document the project goals and the necessary actions to implement that goal, being that these actions should consider the project elements necessary to implement the described objective. The BIM goals should be chosen by the planning team and should be consistent with the project´s scope baseline, the stakeholders´ requirements and expectations, the participants´ goals and capabilities and the desired risk allocations. In addition the BIM goals should be measurable, and strive to improve the success of the project (CIC, 2011). Furthermore, the planning team should measure the priority (High/Medium/Low) of the project´s goals that were previously outlined in order to have a superior grasp of the significance of each goal to pursue.

After the goals are defined the team should identify the appropriate BIM Uses to fulfill them. As such, this guide suggest the consultation of the study developed by the Computed Integrated Construction Research Program, which identifies twenty five generic BIM Uses by project´s phase (Annex 2). Each description includes an overview of the BIM Use, potential benefits, required team competencies, and selected resources that can be referenced for additional information about the BIM Use. If necessary other BIM Uses not inserted in this list can be used if the team consider necessary for the accomplishment of a certain criteria of the project. At Table 4.7 it is outlined how the BIM goals and possible uses should be documented.

Table 4.7- Structure to register the project goals description and possible BIM Uses

Goal description	Priority (High /medium/ low)	Actions for the goal implementation	Possible BIM Uses
Exact as-built	High	Definition of the requirements of the as-built and correct definition of the model data	Facilites management
(...)			

4.4.2- BIM Goals control

Taking into account that change is inevitable, some type of change control process is mandatory for every project (PMI, 2013). After the BIM goals are defined it is important to define how they are going to be controlled. This is the process of monitoring the status of the project and BIM goals, helping the team to manage possible changes to the goals or scope baseline.

The team should document the results that verify the goal achievement giving a concrete way of measuring the goal completion, and therefore the quality of the deliverables and of the project. This helps the team to verify if the project is going as planned or if not to make a variance analysis, assessing the cause and degree of the difference between the baseline and actual performance. Important aspects of project scope control include assessing the cause and degree of variance relative to the scope baseline and deciding whether corrective or preventive action is required (PMI, 2013). At Table 4.8 it is exposed the proposed way of controlling the BIM goals, being that the team should define appropriate checkpoints for each goal, taking into account that an undetected change of the project can have implications to the time, cost and resources of the project.

Table 4.8- Structure to register the project goals control

Project Goal	Checkpoints/Timeframe	Results that verify the goal achievement
Exact as built	End of design phase	The as-built is complete and precise, achieving all the defined requirements and facilitating the navigation and access to the information
(...)		

4.4.3- Selection of the BIM Uses

After the team has the potential BIM Uses defined, it should define which of them are going to be implemented. This analysis of BIM Uses should initially focus on the desired outcomes for the overall process. The selection procedure will consider the characteristics of the project and the BIM competencies of the involved stakeholders regarding the implementation of the potential BIM Uses.

For the selection procedure it is recommended that the team discuss the potential impact and effort for each use as it is suggested in the Guide to BIM Execution Planning (University construction management council, 2013). For the impact, the team should assess which risks can be reduced and mitigated with the usage of each BIM Use and what are the alignment with a specific project goal. To assess the effort the team should assess the needed resources and time for the usage of each BIM Use, and the commitment degree of the team.

The selection methodology of this guide is based on the procedure used in the BIM Project Execution Planning Guide Version 2.1 (CIC, 2011), in which it is created a BIM Use selection worksheet presented at Table 4.9.

The BIM Use selection worksheet of this guide will contemplate the following details:

- Potential impact:

-Potential BIM Uses for the project: Potential BIM Uses identified at the “identification of the BIM goals and possible BIM Uses” point;

-Risk mitigation: The team should resort to the 4.2.4- section and evaluate if the BIM Use can mitigate or eliminate some of the risks identified;

-Value to the project: The value to the project of the BIM Use is defined considering the alignment of the use with the project goals, being that one BIM Use can be useful for more than one BIM goal, and the classification priority considered for that goals.;

-Responsible stakeholders: for each BIM Use considered, at least one responsible stakeholder for its execution should be considered;

-Value for the responsible stakeholder(s): There should be assessed the value of the BIM Use for the responsible stakeholder(s), being that each stakeholder has its own requirements it can be a way to evaluate the motivation and keeping the stakeholder interested in the project;

- Potential effort:

-Capabilities rating: The planning team should create a fair process of evaluating each party capabilities, and if possible with the assistance of the key stakeholders, being that the capabilities will be quantified by attributing a number between one and five (one is lower and five higher). The capabilities rating should include the resources needed to implement BIM (Software, hardware, BIM team, and others), the BIM competency (if the team has the know-how to implement the BIM Use), the party experience in the implementation of the BIM Use and the commitment with the BIM Use (amount of effort that the party is able to put into the implementation of the BIM Use);

-Additional resources/ Competencies required to the implementation: The team should specify when convenient, the additional resources/ competencies needed in order for the party to implement the respective BIM Use, if additional training actions are required the team should plan and register them in the section 4.5.3-;

-Required time for the implementation: The time should identify the planned work hours necessary for the implementation of each BIM Use considered, taking into account that if a BIM Use consumes too much time it may not be complete or available in a timely manner;

-Notes: The team should investigate and register if there is an additional value gained, as well as additional project risk associated with the implementation of the BIM Uses;

-Proceed with use: The team must discuss in detail the implementation or not of each BIM Use, considering their potential impacts and efforts. It should be also noted that the implementation of a determinate BIM Use can leverage the implementation of other use.

Table 4.9- BIM Use selection worksheet

	Potential impact					Potential effort							
BIM Use	Risk mitigation		Value to the project	Responsible stakeholders	Value for the responsible stakeholder (s)	Capabilities rating				Additional resources/ Competencies required to the implementation	Required time for the implementation	Notes	Proceed with use
						Scale 1-5							
	Project Risk	Risk mitigation capabilities	High/ Med/ Low		High/ Med/ Low	Resources	Competency	Experience	Commitment with the BIM Use		Scale 1-5		Yes/ No/ Maybe
Cost estimation			High	Constructor1	5	1	2	1	1	Complementary formation	(…)	(…)	yes
	(…)	(…)	(…)	Constructor2	1	3	1	2	2	(…)			
					Constructor3	3	2	2	3				

4.4.4- Identification of the BIM Uses on different project phases

After the BIM Uses to implement on the project are chosen, they should be placed considering the phases of the project. It is recommended for this phase that the planning team study the elements to be delivered in each phase of the project, helping to decide which models should be created at each phase. The Table 4.10 illustrates the BIM Uses recurrent on the project phases.

Table 4.10- Identification of the BIM Uses on different project phases (CIC, 2011)

X	Planning	X	Design	X	Construction	X	Operation
	programming		design authoring		site utilization planning		building maintenance scheduling
	site analysis		design reviews		construction system design		building system analysis
	phase planning (4d modeling)		3d coordination		3d coordination		asset management
	cost estimation		structural analysis		digital fabrication		space management / tracking
	existing conditions modeling		lighting analysis		3d control and planning		disaster planning
			energy analysis		record modeling		record modeling
			mechanical analysis		phase planning (4d modeling)		phase planning (4d modeling)
			other eng. analysis		cost estimation		cost estimation
			sustainability evaluation		existing conditions modeling		existing conditions modeling
			code validation				
			phase planning (4d modeling)				
			cost estimation				
			existing conditions modeling				

4.5- BIM positions, responsibilities and training actions

Once the project goals and BIM Uses are decided the team should define the roles in each organization and their specific responsibilities, helping the team members to know what are their roles on the project. Along with the defined BIM positions it should be registered who is responsible for implementing the BIM Uses and developing the models, being that advance planning around which models will need to be created during the different phases of the project, and predetermining the content and format of models as much as possible will help the project run more efficiently and cost-effectively during every phase (Indiana University, 2012).

In addition, at this phase, it should be decided which training actions should be prepared thorough the project to increase the competencies and capabilities of the teams to optimize the performance of the project. The description of the BIM positions, responsibilities, and the identification of the organizations responsible for carrying the BIM models and uses are already well developed at the existent BEPs and norms, and according with the PMBOK. Although at this chapter it is going to be added a topic relating to training actions, as it is recommended on the PMBOK.

4.5.1- Description of BIM positions and their responsibilities

Each project team member shall have specific responsibilities respecting the use of BIM on the project, and therefore it should be described the main roles in each organization, their responsibilities and authority. The objective is to ensure that each work package has an unambiguous owner and that all team members have a clear understanding of their roles and responsibilities (PMI, 2013). At Table 4.11 it is represented how the positions should be registered along with some examples that should be modified according with the dimension and scope of the project. The defined examples are based on the defined positions from “A Standard Framework and Guide to BS 1192” (Richards, 2010).

Table 4.11- Main roles and their responsibilities (adapted from Richards, 2010)

Position	Main responsibilities and inherent Authority
Design coordination manager	Provide the communication link between the design and construction teams. Usually provided by the contractor this role integrates the design deliverables against the construction program to ensure a delivery on schedule. In addition this person should be responsible for the folder maintenance and file naming.
Lead designer	Manages the design, including information development and approvals. The lead designer confirms the design deliverables of the team and establishes the zone strategy and ownership. In addition is the person responsible for approving the documentation before it passes to the “shared” area in the CDE.
Task team manager	Responsible for the production of design outputs, enforcing the documents standards. Being that usually the designs are divided by discipline, the task team manager is the disciple head, responding to the lead designer.
Interface manager	The interface manager should be appointed for each task and it is his responsibility to negotiate the space allocation. If a team needs more space in a certain area of the design it should be discussed with the interface manager. The interface managers should answer to the task team manage and to the lead designer.
Project information manager	Responsible for enforcing the project BIM standards and ensure delivery of the Stakeholders´ information requirements. The project information manager should respond to the design coordination manager.
CAD coordinator	Enforces the CAD related project BIM standards, and ensures that there is a consistent approach to project modeling and CAD issues and practices throughout the project. The CAD coordinator should be responsible to the task team manager and the project information manager.
Construction managers	Responsible for the site investigation, constructability input, preliminary estimate, preliminary schedule and 4D modeling
(...)	

4.5.2- Responsible organizations for carrying out the uses and BIM models

The planning team should define for each selected BIM Use which organization(s) will implement that use, which will give a better perception to the organizations of their role on the project and a possible way to determine the human cost of each BIM Use. This should be registered at Table 4.12, along with the number of necessary employees, the estimated work hours and the location that will complete the BIM Use. This task can be difficult to complete in the beginning of the project and, therefore, it should be constantly updated along with the availability of the information.

Table 4.12- Structure to register the organization(s) responsible for implement the BIM Uses (adapted from CIC, 2011)

BIM Use	Organization	Number of employees	Estimated work hours	Location (s)	Primary contact
Design authoring	ABC	20	123	ABC	123
(...)					

In addition, throughout the project the project team may have to generate multiple models. Even when the team is committed to using IPD, creating separate models is sometimes necessary, based on contractual obligations, risk factors, and the functional intent of each model (Autodesk, 2010). The register of the models that are going to be created for the project should be made as specified in Table 4.13, and it should include the general content of the model, the project phase, when the model will be delivered, the authoring team, and their creation software.

Table 4.13- Structure to register the planned models

Model name	General content of the model	Project phase	Authoring Team	Creation software	Primary Contact
Arc model	As-built defined according with the LOD specifications	Design	Architect	ABC	123
(...)					

4.5.3- BIM training actions

At this point the team should define which organizations should have their competencies developed to enhance project performance. Developing the project team improves the people skills, technical competencies, and overall team environment and project performance (PMI, 2013).

The team should think about the different factors that can influence the project collaborative process. A better collaborative ambient can be created by improving the feeling of trust and agreement among team members, lower conflict and increase team work, which can be achieved by allowing cross training and mentoring between team members (PMI, 2013). Also, the planning team should resort to the BIM Uses Selection Worksheet where were defined the needed competencies of each team to perform the assigned BIM Use, and analyze if the implementation team has the needed competencies to perform it, or if it necessary to schedule training actions to improve their knowledge and skills. Even if the team has the necessary competencies this procedure can reduce schedules, improve quality and lower the project costs. At Table 4.14 is presented how the team should register the training actions and its frequency.

Table 4.14- Structure to register the training actions

Training action	Aspect to improve	Frequency	Participants
IFC formation	Better comprehension of the IFC data model in order to improve the information exchanges	One time	Stakeholders that are going to receive or send information
(...)			

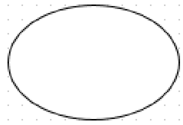
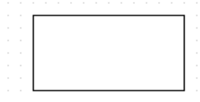
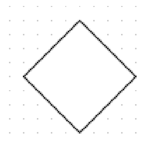
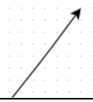
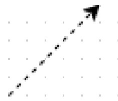
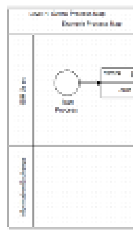
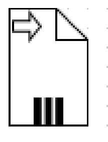
4.6- BIM process mapping

After each BIM Use and the organizations responsible for their implementation are identified it is necessary to understand and organize the implementation process for each BIM Use and for the project as a whole. The following procedure of this guide consists on mapping the processes and activities that ensure the BIM workflow as a collaborative project, showing where the team is and where it needs to go to solve their particular issues.

The process maps that result from this procedure allows the team and the stakeholders to recognize the overall BIM process and to gain a shared view of each process that they support by giving the process a better transparency, with indications regarding the dependencies and information exchanges between BIM Uses and the diverse activities to be performed within each BIM Use. The process of making and documenting these maps is a step towards gaining team efficiency by making the team to reflect about what is necessary to carry out each BIM Use and identify synergistic activities between BIM Uses, insuring that there are no missed steps. It also helps the team to recognize and address all potential issues from the beginning to the end of the project. Developing a process map can reveal non-value added activities, complicated work flows, redundant activities, bottlenecks, excessive process dependencies (University construction management council, 2013). These process maps will also serve as the basis for identifying other important implementation topics including contract structure, BIM deliverable requirements, information technology infrastructure, and selection criteria for future team members (CIC, 2011).

The procedure presented in this guide is based on the methodology presented in the BIM Project Execution Planning Guide Version 2.1 (CIC, 2011), although some points are going to be modified in order of approaching with the project management best practices, as the implementation of the RACI matrix at the detailed process maps and the addition of a chapter focused on revisions to the maps. This procedure considers two levels of process maps. The first level, designated as BIM overview process map, illustrates the relationships between the BIM Uses and the information workflow along the project. The second level, designated as the detailed BIM Use process map, illustrates the sequencing of activities to be performed in order to achieve each BIM Use. The process maps of this guide are based on the business process modeling notation (BPMN), like in the BIM Project Execution Planning Guide Version 2.1 (CIC, 2011), which is presented at Table 4.15.

Table 4.15- Process mapping notation for BIM process maps (CIC, 2011)

Element	Description	Notation
Event	An Event is an occurrence in the course of a business process. Three types of Events exist, based on when they affect the flow: Start, Intermediate, and End.	
Process	A Process is represented by a rectangle and is a generic term for work or activity that entity performs.	
Gateway	A Gateway is used to control the divergence and convergence of Sequence Flow. A Gateway can also be seen as equivalent to a decision in conventional flowcharting.	
Sequence Flow	A Sequence Flow is used to show the order (predecessors and successors) that activities will be performed in a Process.	
Association	An Association is used to tie information and processes with Data Objects. An arrowhead on the Association indicates a direction of flow, when appropriate.	
Pool	A Pool acts as a graphical container for partitioning a set of activities from other Pools.	
Lane	A Lane is a sub-partition within a Pool and will extend the entire length of the Pool - either vertically or horizontally. Lanes are used to organize and categorize activities.	
Data Object	A Data Object is a mechanism to show how data is required or produced by activities. They are connected to the activities through Associations.	
Group	A group represents a category of information. This type of grouping does not affect the Sequence Flow of the activities within the group. The category name appears on the diagram as the group label. Groups can be used for documentation or analysis purposes.	

4.6.1- BIM overview process map

The BIM overview process map is composed by two lanes. The first lane is designated as “BIM Uses lane”, and is where it is represented the logical sequence of the BIM Uses, where each BIM Use is treated as a process within the map. The second lane is designated as “Information Exchange lane” and it is where it should be included the critical information exchanges that are going to be used by other BIM Uses. The team should start by sequentially order the BIM Uses, identifying in which project phase they are placed, and then connecting them using the “sequence lines” of the BPMN mapping notation, representing which BIM Uses are succeeded and preceded by each BIM Use. Each representation of the BIM Use on the process map should have the use description, indication of its detailed BIM Use process map (level 2) and project phase of implementation. In addition, it should be identified the responsible stakeholder(s) for the BIM Use implementation and for the assessment of the required information to implement the BIM Use as well as the produced information (deliverable). This information is represented at Figure 4.2 and Figure 4.3.

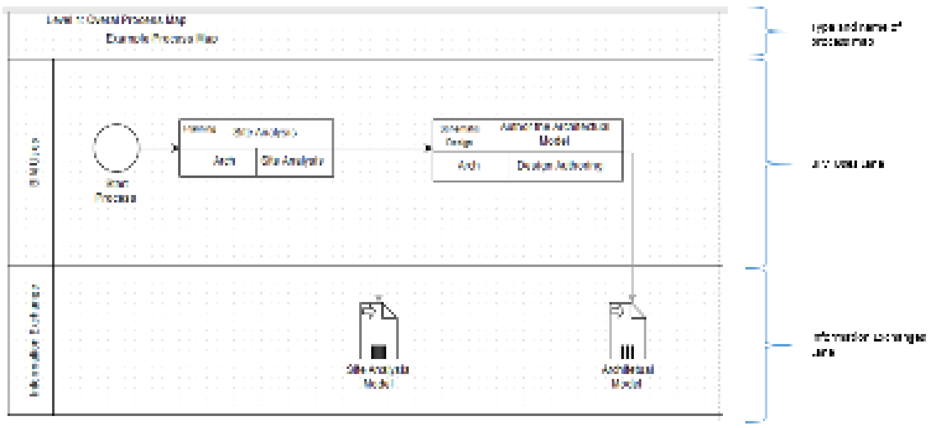


Figure 4.2- Description of the components of the BIM process overview map (adapted from CIC, 2011)

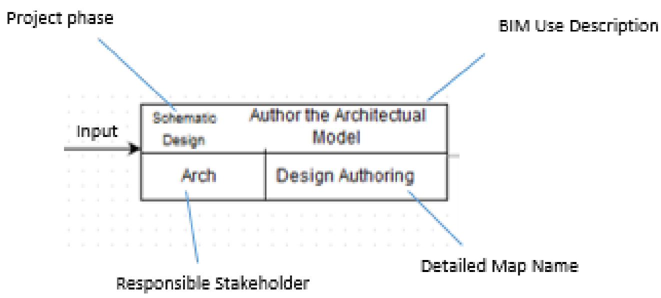


Figure 4.3- Notation of the BIM Use BIM Uses in the BIM process overview map (adapted from CIC, 2011)

The information exchange lane of the BIM overview process map includes the critical information exchanges, where the information can be either internal to a particular process or shared between processes and responsible parties (CIC, 2011). The exchanges originated from a process box are internal to a process, and the exchanges which originate or flow into the sequence line are external exchanges which are shared between high level processes. From this process the stakeholders have a representation of the available information, being that all the information exchanges identified are detailed in section 4.7-.

4.6.2- Detailed BIM Uses process maps

After the creation of the overview map, it should be created for every identified BIM Use a detailed BIM Use process map, which identifies the sequence of the various activities to be performed within that use. These maps should be created by the stakeholder responsible for the respective BIM Use, identified in the BIM overview process map.

Similar to the process presented in BIM Project Execution Planning Guide Version 2.1 (CIC, 2011), each detailed BIM Use process map incorporates three categories of information and, therefore, it incorporates three lanes. The central lane is the “process lane” and represents the logical sequence of activities that constitute a particular BIM Use of the BIM overview process map. The upper lane is the “reference information lane” and identifies the information needed to accomplish the BIM Use (for example: materials, product data, cost databases, and others). After identified all tasks needed to perform a BIM Use in the process lane, the stakeholders should fill the lower lane, which is the “information exchange lane”, which identifies all input (required information) and output information (final deliverables) of each process. All the identified information should simultaneously be documented in the detailed BIM Use process map and in the BIM overview map, allowing the register of the information exchange between BIM Uses.

It should also be added verification gates and decision points to the map, which enables the team to ensure that the pretended results are met. These are points that allow the team to make control check, iteration or decision needed before the completion of the BIM Use. Taking into account that some BIM Uses are developed by more than one stakeholder, it can be useful to assess all the stakeholders associated to each activity of the BIM Use, avoiding ambiguity. To do so this guide proposes the usage of the RACI model, which can have a significantly positive effect on the quality and speed of decision making on significant issues on projects (Chartered Institute of Building, 2014). The model consists in identifying the stakeholders:

- Responsible: Stakeholder(s) responsible for the decision making concerning the activity, being in charge of getting the activity done;
- Accountable: Stakeholder accountable for the correct and thorough completion of the task, approving the completion of the activity, this should be only one person to avoid confusion about responsibilities;

- Consulted: Stakeholder(s) that is an expert on the subject and is available to establish a two-way communication, being useful to provide more information about an activity when doubts are raised;
- Informed: Stakeholder(s) that should be kept informed about the progress and outcome of the activity, these are usually affected by the outcome of the activity. They can be stakeholders expecting an information exchange from the activity.

The components of the detailed BIM Uses process maps are presented at the Figure 4.4 and Figure 4.5.

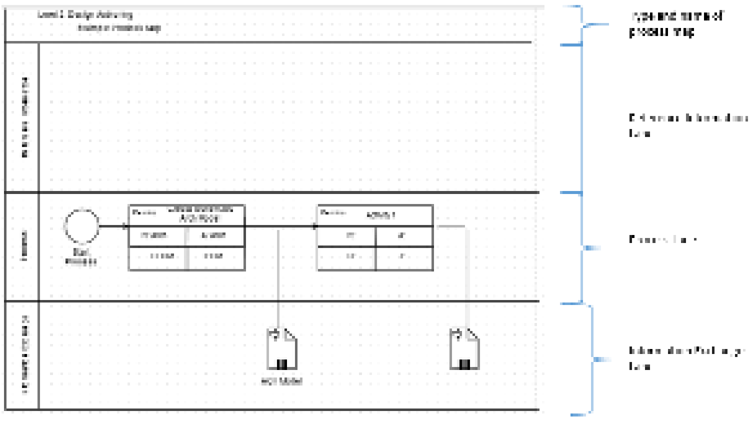


Figure 4.4- Description of the components of the detailed BIM Use process map (adapted from CIC, 2011)

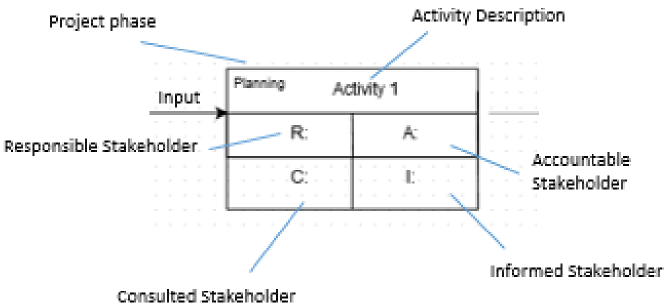


Figure 4.5- Notation of the BIM activities in the detailed BIM Use process map (adapted from CIC, 2011)

4.6.3- Maps review

The planning team should review each process map throughout the BIM implementation process, which can be a useful step both to clarify the processes as to reflect on the processes actually used in practice. As such, the team should set a schedule for the maps review and update them as necessary to reflect the actual workflows implemented on the project. Taking into account that the process maps can be further used for other projects by the team, it can be useful to compare the actual process used versus the planned process in order to improve future works.

4.7- Information exchanges requirements

At this phase of the BIM execution plan the team should define the information exchanges necessary among the BIM Uses and to a successfully BIM implementation. The procedure presented is a compilation of the existing procedures in the Guide to BIM Execution Planning (University construction management council, 2013), BIM Project Execution Planning Guide Version 2.1 (CIC, 2011) and from the protocol 2013 AIA G202 (The American Institute of Architects, 2013).

The information exchanges should be defined after the BIM overview process map and detailed process maps are completed, where it is documented what, when and from whom information exchanges are required. It is important, especially to the author and to the receiver of the information exchange, to clearly understand the information content.

The information exchanges can be distinguished into two groups, the first group refers to the exchanges between project phases, in which the BIM Uses of the upcoming phase depends of the deliverables of the prior phase (for example the "author construction documents" BIM Use of the construction documents phase needs the structural model established in the "author schematic design" BIM Use of the schematic design phase). The second group refers to the exchanges in the same project phase, where there are defined the dependencies between BIM Uses in order to implement all BIM Uses in that phase (for example the "lighting analysis" of the schematic design phase BIM Use requires the architectural and structural models performed by the "author schematic design" BIM Use of the same phase).

To effectively define the information exchanges the team should define the minimum information, geometry and organization required to complete the specific BIM Uses in a timely manner. When that information is defined, it will be classified according with the LOD (Level of development) classification system, in a way that each stakeholder, when authoring a BIM model, knows the level of rigor for each BIM object that is necessary to achieve in order to serve as an adequate output deliverable to the consequent BIM Use. The procedure of defining the necessary information exchanges is composed by 3 steps described in the following sections.

4.7.1- Selection of a model element breakdown structure

The planning team should start by selecting a model element breakdown structure, which is the process of subdividing the project deliverables and project work into smaller, more manageable components. The key benefit of this process is that it provides a structured vision of what has to be delivered (PMI, 2013). The existent BEPs already have this procedure implemented which is in conformity with the project management methodology. This procedure should represent all the building elements possible on a BIM model, and must be comprehensible by all the members involved in the BIM implementation. There are already some classifications systems defined that can be adopted as the model element breakdown structure. Some examples are the OmniClass, or the CSI Uniformats II construction classification systems.

4.7.2- Minimum information requirements of the selected BIM Uses and their classification according to the LOD specification

Each of the selected BIM Uses must have made the definition of the minimum information requirements, in terms of the needed information and geometry to successfully be implemented. This is the necessary “input information”, and should be defined by the model receiver, whom is the stakeholder or team member that needs the information to perform a BIM Use. In order to define the “input information” each stakeholder(s) should consult the Detailed BIM Use Process Map of the correspondent BIM Use, to identify the necessary information to perform that BIM Use.

Based on the existing information exchange inputs, the stakeholder should list the minimum required information and geometry features of each building element to execute that BIM Use. If necessary, there are some protocols, such as the Singapore BIM Guide, which can help the stakeholders to define the minimum information requirements at each phase.

Once the responsible stakeholder has documented the minimum information requirements for their BIM Use(s), that information should be classified according with the LOD (Level of Development) specification defined in the AIA G202. This classification system enables the involved stakeholders to assess the minimum information requirements regarding the level of modeling rigor and information detail of each BIM element. For the definition of the LOD it is important to distinguish level of detail from level of development, being that level of detail is the amount of information and geometry provided by the modeler and level of development is more concerned with reliability. In essence, Level of Detail can be thought as an input to the element, while Level of Development defines reliable output, being that a determined object can have a lot of information (great level of detail) but not be accurate (low level of development).

The procedure of classifying each defined information requirement of each building element should begin by comprehending the definitions of each LOD category. These categories are grouped in Table 4.15. In addition the AIA G202 protocol also refers the authorized uses for each LOD category, to verify if the stipulated LODs are sufficient to capacitate the BIM Use implementation.

Table 4.16- LOD definition and authorized uses (adapted from AIA G202, 2013)

LOD	Definition
100	Model elements may be represented in the model with a symbol or other generic representation but not satisfy the requirements for LOD 200. Information related to the Model Element (i.e., cost per square foot, etc.) can be derived from other Model Elements.
200	Model elements are modeled as generalized systems or assemblies with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.
300	Model elements are modeled as specific assemblies accurate in terms of quantity, size, shape, location, and orientation. Non-geometric information may also be attached to Model Elements.
400	Model elements are modeled as specific assemblies that are accurate in terms of size, shape, location, quantity, and orientation with complete fabrication, assembly, and detailing information. Non-geometric information may also be attached to Model Elements.
500	Model elements are field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements.

With the definition of the LOD, the building element under analysis should be classified by correlating the defined minimum information required with the categorization in the LOD specifications. This procedure should be made to every building element and to every BIM Use. It is important at this phase to point that the LOD is based on individual objects or assemblies and not on models. Therefore, there is no such thing as LOD300 model as, although it is possible to have a model that contains all the objects at LOD300, it is highly improbably due to different objects progress at different paces. If necessary, and if with the LOD classifications there is still doubt about a given building element, the 2014 LOD specification (BIM Forum, 2014) should be consulted, which defines and illustrates characteristics of model elements of different building systems at different Levels of Development. NATSPEC BIM Object/Element Matrix (NATSPEC, 2011) can also be consulted, as it defines a large number of objects and elements and their properties by Uniformat/ OmniClass classification and Level of Development (LOD) at different stages in the building's lifecycle.

When collaborating with different stakeholders the LOD specification eases the communication regarding the technical aspects of BIM models. In addition, the attributed LODs of each BIM Use can be programmed in the contractual agreement, which obligates the stakeholders to accomplish the stipulated LOD.

4.7.3- Definition of the information exchange requirements

After the minimum information input is defined, it is necessary to define the output to complete the information exchange requirements of each BIM Use. To ascertain the required information output, it is necessary to evaluate the highest required information input regarding the immediate dependent BIM Use of the project phase.

All the information exchange requirements are incorporated in the BIM information exchange requirements worksheet, represented at Table 4.17, which was based on a similar worksheet presented in BIM Project Execution Planning Guide Version 2.1 (CIC, 2011). This worksheet is defined by three parts, being that the first part defines the BIM Uses by registering: its project phase, if it requires (input) or creates (output) information, the necessary BIM models for its development and the native format and shared format of the BIM models. The second part represents the building elements that are integrated in the BIM models (model element breakdown), indicating if they are included as 2D elements, 3D elements, only as data or not included at all. The third part of the worksheet registers for each building element the LOD to accomplish and the correspondent stakeholder responsible for its creation (model element author). When the worksheet is completed it should exist a verification for conflicts (for example if the LOD of the output is smaller than the necessary input), and when these are discovered the model element author should be notified, being his responsibility to mitigate the conflict.

Table 4.17- BIM Information Exchange Requirements worksheet

BIM Use Title	Programming
Project Phase	Planning
Type of Information Exchange (Input/output)	
Time of Exchange (SD, DD, CD, Construction)	
BIM model(s) involved	
Receiver File Format (example: IFC)	
Application and Version (Example: Autocad 2013)	

Model Element Breakdown- CSI Uniformat 2010		Model element (3D) included (Yes/No)	Model element (2D) included (Yes/No)	Data only (Specs) (Yes/No)	LOD	Model element author (MEA)	Notes
A	Substructure						
A10	Foundations						
A1010	Standard Foundations						
A1010.10	Wall Foundations						
A1010.30	Column Foundations						
A1010.90	Standard Foundation Supplementary Components						
A1020	Special Foundations						
(…)							

4.7.4- Model Delivery Schedule of Information Exchanges

After the BIM Information Exchange Requirements worksheet is completed the team should document all the information exchanges defined in the main corpse of the BIM execution plan (the worksheet should be an Annex), documenting all the exchanges in one place. This phase will also help to determine a more precise schedule (not only the phase but a precise date) for the information exchanges, and the frequency of the changes. At Table 4.18 is defined how the schedule of the model information exchanges should be defined, by registering the information exchange sender and receiver, the frequency of this exchange with precise dates and the software and file specifications of the information exchange.

Table 4.18- Structure to register the model delivery schedule of information exchanges (adapted from CIC, 2011)

Information exchange	File sender	File Receiver	Level of development	Frequency	Date (YYYY-MM-DD)	Model file	Software	Native file type	File exchange type
Design authoring to structural analysis	Arc	Structural Engineer	LOD 200	One time	2016-02-14	Struct	ABC	ABC	IFC
(...)									

4.8- Collaboration procedures

The effective communication on a project creates a bridge between diverse stakeholders, who may have different cultural and organizational backgrounds, different perspectives and interests, which affect or have an influence upon the project execution or outcome (PMI, 2013).

BIM is a collaborative methodology, which means that usually there are different models and activities being worked at the same time. Therefore, the good communication and collaboration between the team members and the stakeholders is essential for its effective implementation. It is crucial that the team establish at an early stage of the project a methodology that supports collaboration, in a way that problems originated from lack of communications or poor data management are avoided.

The methods of storage, retrieval, and ultimate disposition of the project information needs to be considered and suitably documented during this process. As such, the PMBOK recommends some considerations to be taken: who needs which information and who is authorized to access that information (see section 4.8.4-); when they will need the information (see section 4.7.4-); where the information should be stored (see section 4.8.5-); which information should be stored (see section 4.8.5-); how the information can be retrieved (see section 4.8.1-); and whether time zone, language barriers, and cross-cultural considerations needs to be taken into account (see section 4.1.1-). This chapter is, as a whole, well-defined according with the project management best practices, and it is going to be based mostly at the existent BEPs and standards, as the BS1992:2007. However, PMBOK is going to be used to improve some of the points like the interactive workspace/cultural references.

4.8.1- Collaboration strategy/common data environment

At this point the team should describe how it will collaborate in general. Communication, document management and transfer methodology should be planned. The team should define the method of communication among themselves and with the evolved stakeholders, while taking into account the urgency of the needed information, the availability of the technology, the sensitivity and confidentiality of the information, and the usability of the technology (PMI, 2013).

This guide suggests that, when possible, the communication should be performed in an interactive way, being the most efficient way of communication (PMI, 2013). Methods of communication includes meetings, phone calls or video conferences, being that this guide suggests the utilization of meetings (see section 4.8.2-). When the communication is sent to a specific receiver it can be made of letters, email, reports, or other means, although this way does not ensure that the information is correctly exchanged or comprehended and, therefore, it should be used with more discretion.

This guide recommends that the team follow the methodology presented in the BS1192:2007 and summarized in the AEC (UK) BIM Protocol V2.0, for the management of BIM data, helping to promote a collaborative culture. The methodology is to create a common data environment (CDE), which allows the information to be shared between all stakeholders, and defines the collaborative working process for project collaboration and efficient data sharing (AEC BIM Protocol, 2012). Some advantages of the CDE are: ownership of information remains with the originator, and even though it is shared and reused only he can change it; shared information reduces the time and cost in producing coordinated information; any number of documents can be generated from different combinations of model files (PAS 1192-2, 2013).

There are four areas relevant to a CDE: the work in progress area, the shared area, the published/issued area and the archive area, as it is represented at Figure 4.6.

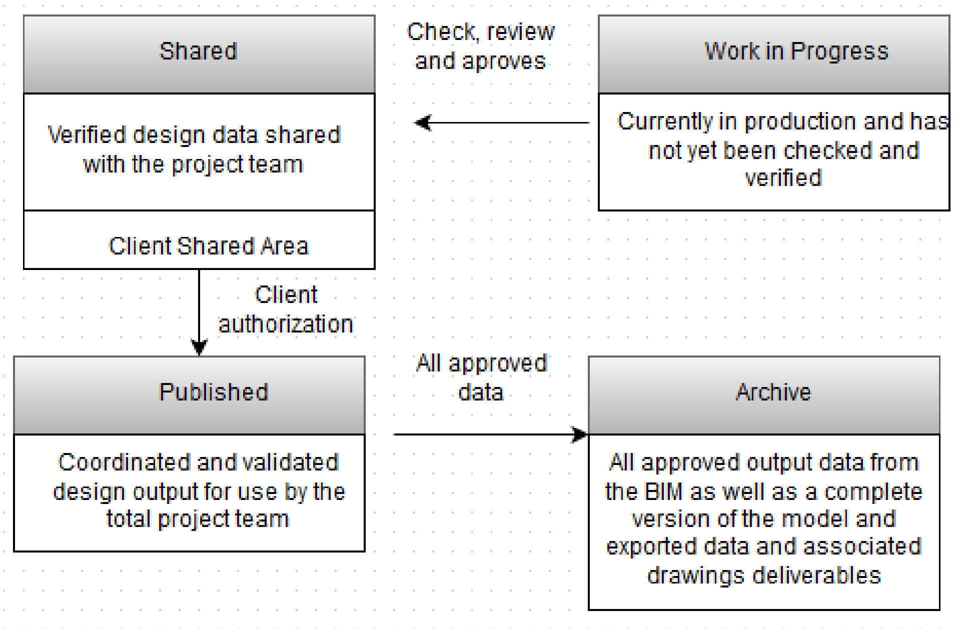


Figure 4.6- Representation of the collaborative process (AEC-UK, 2012a)

Data described as “work in progress” is currently in production and has not yet been checked and verified for outside use of the authoring team. This area is used to hold unapproved information for each organization, and it is only used by the authorized members of the discipline.

When the lead designer of each discipline checks, reviews and approves the model suitability, the standard methods and procedures, the technical content, the drawings extracts along with any additional documentation that is shared as a coordinated package of information and after the task team manager approval, the data is transferred for the shared area (PAS 1192-2, 2013). This area is accessed by everyone from a central location, or replicated in the shared area of the project folder structure of each party, this allows the information of each discipline to be used as reference material for the design development by other organizations and a multidisciplinary revision of the data. When the design is completed the information should be placed in the client shared area for authorization.

Then, the information must be authorized by the client or the client representative to follow to the published area, being accessible for reference during the rest of the project. For this authorization, checks for compliance with the client´s information requirements deliverables and for the quality assurance (see section 4.8.5-) should be completed.

All approved output data from the BIM shall be stored in the archive section of the project folder.

4.8.2- Meeting procedures

Meetings are required to maintain effective communications between the project manager, project team and stakeholders, being the most appropriate way to update and communicate project information and answer requests from various stakeholders for that information (PMI, 2013). The team should define the frequency, location and participants of the meetings, taking into account that meetings held too frequently can lead to a waste of time but infrequent meetings can lead to insufficient communication. The schedule of meetings, forces the team to think ahead about when, how and how often they should take place, being a good way to plan the project communications (Mulcahy, 2013).

Meetings should be prepared with a well-defined agenda, purpose, objective, and time frame and should be appropriately documented with meeting minutes and action items (PMI, 2013). Table 4.19 exposes how the meeting procedures should be registered. This table also shows a suggestion of BIM meetings.

Table 4.19- Example of meeting procedures (adapted from University construction management council, 2013)

Meeting	Main objectives	Estimated duration	Phase of the project	Frequency	Participants	Location
1	Kick-off (introduction to BEP) Team milestones	120 minutes	Project	One time	Owner, architect, engineer (s), project manager, BIM manager	
2	BIM Uses Software Risk management	120-180 minutes	Project	One time	Owner, architect, engineer (s), project manager, BIM manager	
3	BIM Plan Review	60 minutes	All	Monthly	Owner, architect, engineer (s), project manager, BIM manager	
4	Standards model management	60 minutes	Project	One time	Owner, architect, engineer (s), project manager, CAD coordinator	
5	Level of development	180 minutes	Project	One time	Owner, architect, engineer (s), project manager, information exchanges manager, project information manager	
6	Sign Off (Final BEP) Next steps	30 minutes	Project	One time	Owner, architect, engineer (s), project manager	
(...)						

4.8.3- Interactive workspace/cultural references

The planning team should consider the needed physical environment throughout the lifecycle of the project, including where the meetings will occur and the necessary equipment and conditions to maximize the collaboration, communication and the decision making process. This action can cause an improvement in communication between stakeholders and in collaborative work. In addition, if video conferences are considered it should be taken into account factors like time zone, software implications or country restrictions (PMI, 2013).

4.8.4- List of the model managers

In the follow up of the collaboration strategy and the creation of the common data environment, each discipline/organization should consider the members that have the authority to upload, download, and change the access of the document. These members are the model managers.

This will allow a better coordination in order to distribute all the organization documents to a limited group of members, and restricts the skills to the team members, preventing, for example, the upload of multiple similar documents. In addition, the register of the model managers elucidates who has the authority to distribute a file to different areas of the common data environment.

The responsibilities of the model manager may include: transferring modeling content from one party to another; validating the level of detail and controls as defined for each project phase; validating modeling content during each phase; combining or linking multiple models; participating in design review and model coordination sessions; communicating issues back to the internal and cross-company teams: keeping file naming accurate; managing version control; and properly storing the models in the collaborative project management system (Indiana university, 2012). The identification of the authorized manager and its type of authority should be done as demonstrated at Table 4.20.

Table 4.20- Structure to register the authorized model managers

Organization	Discipline	Model manager name	Email	Type of authority (Upload, download, change access/distribution)
ABC	Structure	ABC	ABC	Change access
(...)				

4.8.5- Electronic communications Procedures

The team should define the electronic communications protocol with all the project members. The files names and structure should be defined at section 4.11- and the model and data access rights for the project should be defined at this stage. The BIM model manager should manage all model access rights that include the creation, deletion, and modification of elements, assuring that only authorized users of the model can add the files for their respective component model(s). At Table 4.21 it is represented the structure of how the model and data access rights for the model should be registered in conformity with the common data environment, being that the permissions can be of four types: view permission (V); modify permission (M); download permission (D) or no access permitted (N). In addition, there are some examples of how the table can be filled, being that the stakeholders defined are: the owner (O), the architect (A), and the contractor (C).

Table 4.21- Structure to define the model access rights

File Structure						Password protected	Updates	Project Stakeholders			
						(Yes/ No)		O	A	C	…
BIM											
	WIP Area										
		CAD									
			Architect CAD files			No	Daily	D	M	M	,,,
			…								
		BIM									
			…								
		Sheet files									
			…								
		Export									
			…								
		Families									
			…								
		WIP_TSA									
			…								
	Shared Area										
		CAD									
			Architect CAD files			No	Finished	D	V	V	…
		BIM									
			…								
		CoordModels									
			…								
	Published Area										
		YYY.MM.DD_Description									
			Submission files								
				…							
	Archived Area										
		YYY.MM.DD_Description									
			Archived files								
				…							
	Incoming										
		Source of data									
			YYY.MM.DD_Description								
				Incoming files							
					…						
	Resources										
		Title Blocks									
		Logos									
		Standards									

4.9- Quality management

At this phase the team should plan the quality management to guarantee the quality of the project. The team should invest in the quality of two main points, the first is the project management related topics (cost, process, time, satisfaction of the client, among others), and the second is the quality of building designs according to what BIM-based design currently enables, which means that there should be a control of the BIM files and of the accuracy of the models. The project management related topics are very underdeveloped at the considered BEPs and are going to be added points like the key performance indicators, the change requests and the nonconformities treatment as it is recommended at the project management best practices in order to have a better control of the project's quality. The quality of building designs and BIM files is going to be based on existing norms and BEPs, being that these points are specific to BIM related projects.

There are two main goals in doing the quality assurance, firstly the quality assurance of each designers own design work is improved and secondly the exchange of information between parties is better controlled, which means that the overall design process is more effective (COBIM 2012c). Quality assurance of BIMs is a joint effort of the designers and the client, the purpose of which is to improve the quality of the design solutions, their conformance to the client's needs and the predictability of the construction schedule and costs, to ease the construction stage, to reduce the amount of modification design required during construction, and to ensure a functional, high-quality building as the end result (COBIM, 2012c).

The following sections discusses which BIM files should be checked, why and how the key performance indicators should be defined, which verifications can be made to check the BIM files, and why is it important to define tolerances for the models. The causes of variances, the reasons behind the action plans chosen to deal with those variances, and other types of lessons learned from the quality management should be document to become part of the historical database for both the project and the performing organization (PMI, 2013).

4.9.1- BIM files to be controlled

The team should define how BIM files should be checked to verify the integrity of the BIM project. The proposed control method of this guide is based on the COBIM v1.0 2012, which defines five level of extent and purpose to be verified, being that the levels are: the inventory BIM, the spatial BIM, the building element BIM (architectural and structural), the system BIM, and the merged BIM.

To control files this guide suggests that the planning team defines a quality checklist, which is a structured tool, usually component-specific, used to verify if a set of required steps has been performed (PMI, 2013). The COBIM v1.0 2012 ("quality assurance") already defines checklists for the BIM files, which can consulted and modified for the project incorporating the defined project scope and acceptance criteria. Table 4.22 displays an example of some BIM files that should be controlled along with their description.

Table 4.22- Structure to register the control instructions of the BIM files (adapted from COBIM, 2012)

BIM Files	Description	Control instructions
Inventory BIM	Documentation of the starting situation for renovating construction (example: Spaces and building elements of the existing buildings)	
Spatial BIM	Design of the BIM spaces (example: space objects, building envelope)	
Building element BIM (architectural and structural BIM)	Building elements defined in a Building Element BIM (example: frame structures, foundations)	
System BIM	BIM systems (example: mechanical, electrical and plumbing system BIM)	
Merged BIM	A BIM merged from BIMs of different domains of design, making possible to review them together to assess their compatibility	

4.9.2- Quality control checks

The team should define how the product is examined to assess if it in accordance with the defined standards and requirements. The control checks at this point are more concerned with the quality of the BIM files and models and how is verified. The quality of the project management related topics is analyzed at section 4.9.3-.

Each project's team member should be responsible for performing quality control checks of their deliverables, and when there is an exchange of BIM models, a more rigorous control check should be made to ensure an effective information change. Therefore, each party should point a responsible member to ensure that the quality control of the models and data has been followed before accepting model revisions (COBIM, 2012c). Table 4.23 defines some control checks that should be verified based on the control checks presented on the BIM Project Execution Planning Guide Version 2.1 (CIC, 2011).

Table 4.23- Structure to register the control checks of BIM files and models (adapted from CIC, 2011)

Verification	Definition	Responsible entity	Software	Frequency
Visual	Check if there are no unintended model components and if the design intent has been followed			
Interference	Detect problems in the disciplines model where two components are clashing including soft and hard			
Standards	Ensure that the BIM Standard have been followed			
Model Integrity	Ensure integrity of the model aligns with BIM Uses and client's BIM specific modeling and documentation requirements and standards, as set out in Model Standards.			
Design review	Review that the ongoing development of the model is aligned with the client objectives			

4.9.3- Key performance Indicators

Performance management should be an integrated part of a development project from its definition to monitoring and review (Chartered Institute of Building, 2014). To assess the correctness of any information, it must be possible to compare or measure it against some reference information.

Being that the method to control the BIM files and models is defined at sections 4.9.1- and 4.9.4-, the method that this guide suggests to evaluate the progress of the project (cost, calendar, among others) and the performance of the used processes is by creating some key performance indicators (KPIs)to periodically assess the performance and effectiveness of the project delivery as well as individual stakeholders (AEC BIM Protocol, 2012). For example, the team should define which percentage of correct BIM files should be in conformity before a measure is taken.

It is important at this point to define the cost of quality, which refers to the total cost of the conformance work and the nonconformance work that should be done as a compensatory effort, as on the first attempt to perform that work some portion of the required work effort may be done or has been done incorrectly (PMI, 2013). To minimize the cost of quality the team should have the perception of the degree of quality that the project must have, taking into account the risk of not meeting the requirements. This mean that ensuring correct and quality BIM files on the project can be more expensive than admitting a certain degree of inaccurate BIM files or risks on the project.

For the definition of the KPIs the team should fill the following attributes: the KPI should encourage the right behavior; should be measurable; should be affordable (cost-effective); the value targeted should be attainable according with the possibilities; the factors affecting the KPI should be controlled by the team responsible; and the KPI should be meaningful (Arayici et al, 2011). In addition of defining the KPIs it should be defined some points in which they are going to be audited, which can help identifying nonconformities, as well as good practices and methods being implemented. At Table 4.24 is presented how the KPIs should be registered along with some examples of KPIs defined.

Table 4.24- Structure to register the project KPIs with examples

Key Indicator	Definition/Reference
% Of requirements met perfectly	The minimum general requirements met perfectly is of 90%
Review of documented information	Review of 20% of the documented information, admitting a maximum of 5% of errors
Number of conflicts/nonconformities detected	The number of nonconformities detected at work in revision should be less than 35 %, but none that prevents the next step of the project
Recurrence of nonconformities	If there is a large recurrence of nonconformities something in the system is not working well. It is admitted a recurrence of 30% of nonconformities treated
Condition of approval of documents	Review of important documents of the system, investigate whether there are processes without documents or who suffer from too many revisions. Do not admit processes without proper documentation
Number of man hours spent on the project	Evaluation of the efficiency of the BIM system through this parameter, with the objective of comparing with the same parameter without the use of BIM
Progress of The as-built drawings	Do not admit delays in relation to the times defined
(…)	

4.9.4- Model accuracy and tolerance

The team should define the model accuracy and the admitted tolerance. It was decided to separate this point from the key performance indicators, as this point is model accuracy related and it is essential to highlight the importance of defining an accurate model. Models should include all appropriate dimensioning as needed for design intent, analysis, and construction (Indiana University, 2012). Therefore, any significant differences from the pretended and the underlying reasons must be examined, to determine whether the difference refers to a problem that requires further action. At Table 4.25 some examples of what should be registered at this point are presented.

Table 4.25- Structure to register the model tolerances

Project phase	Discipline	Tolerance
Design documents	Architecture	Accurate up to 5% of the real size
Shop drawings	CM	Accurate up to 10% of the real size
(…)		

4.9.5- Nonconformities treatment

At this phase the team should describe how it is going to deal with failures in the defined requirements of quality. This can be beneficial for the identification of the causes of poor process or product and for analyzing the necessary actions to eliminate them, ensuring that the deliverables meet the requirements specified.

During the project there are going to be quality assessments to the defined requirements, and either the requirements conforms and no further actions are required, or do not conform, and the team should know how to deal with them. Therefore, operational techniques and tasks should be defined to ensure that the requirements are met, and the nonconformities dealt with. This procedure also provides confidence that the stakeholder´s requirements will be met, and it should be used during the project execution and closing phases.

The team can define this procedure in two different ways, the first is to define an action plan to every key performance indicator, being that this way is more complete and impel the team to think about the processes that define each KPI, how they are managed and what can be made to increase the performance if necessary. Although the approach described is accurate, it can also be much complex and therefore the team can decide to group the possible existing nonconformities and provide a plan for each group. If the team prefers the second approach this guide suggests that the nonconformities should be grouped into: critical if they indicate system breaks; major if they indicate failures of any instructions; and minor if they indicate sporadic failures or they are potential nonconformity.

The action plan should be registered along with a deadline for response and the responsible party for ensuring its implementation. Table 4.26 shows an example of action plans, with examples for the general and specific nonconformities.

Table 4.26- Structure to register the action plan to treat nonconformities with examples

Type of nonconformity	Action plan	Deadline for response to the action plan	Responsible party for monitoring/implementation of the action plan
Critical	Meeting with the responsible entity in order to understand the cause and approve the best corrective action. Change request		
Major	Greater control at the next similar activity		
Minor	Take preventive measures		
Review of documented information	If percent error is greater than 5%, project team is to revise and resubmit information, as to not delay downstream user progress		
Condition of approval of documents	If there are documents without proper documentation, review the process of the approval of documents and resubmit information		
(…)			

4.9.6- Change request

As an outcome of comparing the planned with the actual results, a change request may be necessary. These can be used to give the project a better adaptation to reality. For example, if the BIM goals and objectives are not perfectly adapted to the project, or if the stakeholders' requirements are too demanding or if with the development of the project new requirements are added. In addition, after the team defines the plan to deal with nonconformities, it should be defined how the changes are going to be implemented in the process. If an action requires a change in the BEP, system process or BIM deliverable, a change request should be initiated.

Change requests may include: corrective actions, which are an intentional activity that realigns the performance of the project work with the project management plan; preventive actions, which are an intentional activity that ensures the future performance of the project work is aligned with the project management plan; and defect repairs, which are an intentional activity to modify a nonconforming product or product component (PMI, 2013). The timely implementation of approved changes needs to be verified.

An example of a change request process can be: Identification of the need for change-> change-> evaluation impact of change (time, costs, risk) -> preparation and revision of the change order (decision phase) -> change-> implementation feedback.

4.10- Technological infrastructures

The team should assess the requirements for hardware, software platforms, software licenses, networks, and modeling content for the project (CIC, 2011). It is important for the planning team to ensure that there is compatibility between the technological infrastructures of the stakeholders to avoid misconceptions relating software incompatibilities or insufficient hardware power. This chapter is specific to BIM related projects, based in the existing BEPs, being that it is going to be grouped the best practices of each BEP in order to create the proposed procedure.

4.10.1- Software platform

The stakeholders involved in the project needs to assess which software platforms and version of that software are necessary to perform each BIM Use, and it should also be defined the process for changing and upgrading the software platforms and versions. This is an important step to avoid interoperability issues between stakeholders, being that interoperability is the capability of different software or hardware platforms to communicate, exchange data and use the exchanged information in an accurate and consistent manner.

The Guide to BIM Execution Planning (University construction management council, 2013) identifies three types of basic software: the authoring software, which is used to generate model geometry and data, and should take into account that most software platforms either are used to design authoring or fabrication authoring; the reviewing software, which is used to review the model, extract information and leverage data, usually not allowing the authoring, modification or deleting geometry or data of the model; and the analysis software, which leverages authored geometry and data to perform specialized analysis, for example to perform an acoustical or structural analysis. Once the team determines the appropriate software platform for each BIM Use, it should register it as it is presented at Table 4.27, including the software platform, the BIM Use, the primary discipline to use the platform and the version of the software.

Table 4.27- Structure to register the used software on the implementation of the BIM Uses

BIM Use	Discipline	Software platform			Version
		Author	Review		
Design authoring	Arch	ABC Design application	ABC Review application	ABC Analysis application	Ver.xx
(...)					

4.10.2- Computers/Hardware platform

BIM deliveries often have their inherent requirements of hardware, and it is essential to identify them in order to upgrade the computer to meet those requirements. When the information begins to be shared between stakeholders it is important to ensure that the hardware of the receiver of the information is not less powerful than the hardware of the creator of the information. To ensure that this does not happen, it is recommended that the chosen hardware is the highest demanded and the most appropriate for the majority of BIM Uses. The documenting of the hardware should include the BIM Use, the hardware owner and the hardware specifications as presented in Table 4.28.

Table 4.28- Structure to register the needed hardware forthe implementation of the BIM Uses

BIM Use	Hardware	Hardware owner	Specifications
Design authoring	ABC	Engineer A	Processor, memory storage, graphic, etc
(...)			

4.11- Model structure

To support the collaborative process and the good implementation of BIM it is essential to have a good folder structure organization of the interactive platform and a coherent file naming. This also becomes important to ease the accurate and fast search of information, and to know what information is the most up-to-date. Therefore, at this phase, the planning team should define the folder structure and the file naming system in a way that the productivity of the project team is increased by making the information more accessible.

In addition to this point the planning team should define the measurement and coordinate systems, and the BIM and CAD standards, which helps the different stakeholders and project teams to understand and compare each other's models, increasing the project compatibility and interoperability and simplifying the deliverables development.

This chapter is well developed in accordance with the project management best practices, being that it is specific to a BIM project and has a clear objective to normalize the BIM folder structure, file names and give clear standards for the organizations to follow. This chapter is mostly based on the existing BEPs and guides that present processes to a collaborative process and specific naming policies as the BS1992:2007.

4.11.1- Folder structure

The team should define the folder structure for the BIM project. This guide suggests that the team follows the recommendation of the AEC BIM protocol v2.0 2012, which is based on the principles of the BS1192:2007. The folder structure shall have a designated set of folders for each of the section of the common data environment described at section 4.8.1-, and if a project has a number of separate elements, such as multiple buildings or areas, the folder structure should possess a set of sub-folders representing the various project elements. In addition, it should exist a set of folders for the BIM resources, which can be the templates, definitions or other non-project specific data, with limited write access. In Figure 4.7 is represented the recommended folder structure.

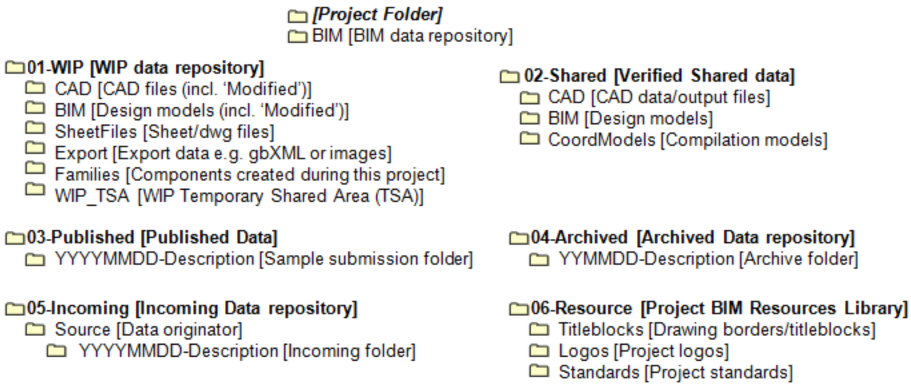


Figure 4.7- Recommended folder structure (adapted from AEC-UK, 2012a)

4.11.2- File naming structure

After the folder structure is defined it is necessary to define how the names of the BIM files will be defined. This step implies a normalization of the files, which allows a better identification and consequently a rapid search capability for all relevant project data and documents.

The file naming structure should take into account the needs of the project as a whole, and of the individual organizations in the wider team, to be able to help all participants of the project, and the necessity to collect, manage and disseminate the data within the common data environment (M. Richards, 2010).

The naming of the model files is recommended to be based on BS1192:2007 and on AEC BIM Protocol v2.0 2012. Figure 4.8 illustrates the recommended convention, being that all fields are optional to be adopted when defining a file identifier, for example a model or drawing. The naming convention includes the following fields:

- Project: is an alphanumeric code that the project team uses to identify the project, where a 3 characters identification is recommended [(for example- TS (technical school)];
- Originator: is an alphabetic code that identifies the responsible stakeholder for the information, where a 2 characters identification is recommended [(for example- CO (construction organization)];
- Zone: is a numeric code that identifies the building, area, phase or zone of the project if the project is sub-divided by zones, where a 2-3 characters identification is recommended;
- Level: is an alphanumeric code that identifies the level, or group of levels, the model file relates to, if the project is sub-divided by levels. It can for example represent the story of the building, where a 2 characters identification is recommended [(for example- 01 (first floor)];

- File type: is an alphanumeric code that indicates the type of file, which identifies the type of information in the file, for example a CAD model file, where a 2 characters identification is recommended [(for example- M3 (3D model file)];
- Discipline: is an alphabetic code that identifies the discipline responsible for the file, where a 1-2 characters identification is recommended [(for example- A (architect)];
- Number: is a 4-6 character code to suit project requirements, and when considered along with the “role”, “originator”, “file type” must present a unique file name. Each discipline number should start at 00001, and then allocates additional numbers to suit its own needs and the first two or three characters of the number could signify an ‘element code’ that further classifies the file. Each field should be separated by a hyphen character “-“.

[Project]- [Originator]-[Zone]-[Level]-[File Type]-[Discipline-[Number]

Figure 4.8- Naming convention (adapted from BS1192:2007)

4.11.3- Model structure

As the BIM projects tend to have a considerable size, they often require the segregation of data into manageable sized pieces. Taking that into account the team should define how the model will be separated, which can be made by various forms, for example by building, by floors, by zones, by areas, and/or by disciplines.

4.11.4- Measurement and coordinate systems

The team should define common modeling units, with the assistance of all project stakeholders. This allows a better model integration, with greater importance when dealing with international stakeholders. The team at this phase should include the scales and units used, location references (for example: geo-referenced or locally referenced origin point), and the coordinate system.

4.11.5- BIM and CAD standards

The items, such as BIM and CAD standards and guidelines, should be identified and agreed upon, being that proposed changes in the deliverables to meet identified quality standards may require cost or schedule adjustments and a detailed risk analysis of the impact to plans (PMI, 2013). This will serve as reference for future consult by the stakeholders, and can take the form of an established industry standard or could be an agreed project specific standard.

This procedure will allow the models to follow a structured methodology in certain aspects, the standards should include how the gross and net floor areas are calculated and registered, and other standards needed for the project. The register of these standards should include the BIM Uses applicable and the organizations that may need to consult this information, as represented at Table 4.29.

Table 4.29- Structure to register the BIM and CAD standards

Standard	Version	BIM Uses applicable	Relevant organizations
EuroCode	Xxx	Structural analysis	Structure engineers
(…)			

4.12- Project deliverables

To implement BIM is essential that each member of the project team understands the expected deliverables and their respective roles. Each deliverable consists of a set of BIM model elements, being that each element is a digital representation of the physical and functional characteristics of an actual building component to be used on the project (BCA, 2013).

The definition of the BIM deliverables of each BIM Use should be according with the stakeholders´ requirements and with the BIM goals and objectives. BIM project deliverables should be agreed upon with deliverable dates at the start of the project and after the main construction members have been appointed so as to accommodate their participations (BCA, 2013).

In order to define the variables the team should look to the BIM process overview map and define the required BIM deliverable to retrieve from each BIM Use implemented throughout the phases of the project, consequently the team must understand the future use of the information (deliverable) to successfully implement the BIM project.

The team should also define which stakeholders are authors or users of the submitted item. The author is the party responsible for creation and maintenance of the specified deliverable considering a defined specific level of detail. The author is the stakeholder authorized to reference, without editing the BIM deliverable. The suggested way to register the BIM deliverables is presented at Table 4.30, and it is based on the Singapore BIM guide (BCA, 2013) and on the BIM Project Execution Planning Guide Version (CIC, 2011).

Table 4.30- Structure to register the BIM deliverables

BIM submitted item	Author	User	Phase	Delivery date (approximated)	Format	Notes
As-Built Model	Arc	Civil engineer A	Design	2016-02-17	ABC	See information exchange worksheet to ensure that the minimum information required is in the model
(…)						

5- Conclusions

5.1- Final considerations

The use of the Building Information Modelling has been increasing on the construction projects, in spite of the implementation of this methodology being a total shift of paradigm that involves some difficulties of implementation, being a complex project that implicates the integration and coordination between all project parties. Therefore, and evermore, it is necessary to create plans for the implementation and development of BIM, in a way that the coordination and responsibilities of a project are defined from the beginning of its lifecycle.

Some of the dissertation´s objectives were not only to demonstrate that the project management bodies of knowledge can improve and be integrated in a BIM implementation but to contribute with an implementation plan of BIM as well, in order to assist the Portuguese companies incorporating the BIM methodology on a project. The suggested plan is made of twelve categories of information and it was shaped by complementing the existing BIM standards and guidelines with the project management best practices. Furthermore, it was completed by performing interviews with AEC professionals in the fields of BIM.

After the developed work it was possible to drawn the following conclusions:

- There are already some well-developed BIM Execution Plans with the most needed information for the implementation of BIM, with special focus on the AEC (UK) BIM Protocol Project Execution Plan, the MIT BIM Execution Plan and the Princeton University BIM Execution Plan Template. In addition, and taken into account some key aspects for the evaluation of the existent BEPs, the most developed BEP was considered to be the BIM Execution Planning Guide;
- Although The BIM Execution Plans are already very complete, they can be complemented with each other and with other guides, being highlighted the COBIM v1.0 2012, the AIA document G202 that indicate modeling and information requirements, and the AEC (UK) BIM Protocol for collaborative requirements. These requirements help the normalization, standardization and creation of a common language (for example the utilization of the LOD classification) in the implementation of BIM, which helps the stakeholders to have a clear understanding of the BIM execution Plan;
- In the development of the BIM Execution Plan, the project leading team is referred multiple times, showing that the leading team is essential to guarantee the good integration and collaboration between the involved stakeholders. It is also demonstrated that evermore the

leading team should understand the project as a whole and be multidisciplinary in order to understand the multiple subjects and developed processes at the plan, maximize the collaborative word and guarantee the project success;

- By comparing the existing project management bodies of knowledge, including the APMBOK and PMBOK, it becomes clear that PMBOK is more detailed, focusing on the management of single projects and taking a more discipline based approach with well-defined processes containing explanations of how to reach the proposed goals. Thus it can be considered that the PMBOK is the most well developed comparing with the other project management bodies, containing more and better explained areas of knowledge, being more adequate to single projects and consequently it was the body of knowledge to consider when implementing BIM;
- When comparing the PMBOK with the BIM Execution Panning Guide it is evidenced that most of the project management areas of knowledge have already some of the processes and best practices applied. However, it is also shown some space for improvement in most of the areas, being that the only exception is the procurement management area and it is only because this area should be the concern of each individual enterprise and not of the BEP itself. So it is evidenced that the BEP can be better implemented when the project management best practices are taken into account;
- It can also be concluded that the bibliography concerning the approach of BIM and project management was successfully extended, being that there were created tables comparing the two and possible synergies between them;
- When analyzing the existing BEPs it becomes evident that the quality management is mostly concerned with the quality of the BIM files and models. With the introduction of the project management practices, there is also a control of the BIM processes. For example, by defining the project management success criteria, by defining some key aspects to control and by introducing a responsibility assignment matrix for each activity. Being BIM a collaborative way of developing a project it is essential to introduce this practices from the beginning, in a way that the project teams become more aware of the practiced processes and their means of control;
- Stakeholders are a crucial part of every project, being that their support can mean the difference between success or failure. The existing BEPs identify them and their requirements, however, with the analysis of the project management practices it could be implemented methods to engage and influence the stakeholders to make the best possible impact. This analysis will allow a better integration and collaboration between the stakeholders and project teams, which means an improvement of the collaborative process and consequently the improvement of the BIM implementation;
- By analyzing the feedback from the interviews it is concluded that BIM experts found the integration between the BIM execution Plan and the project management best practices

useful for the organization of the plan and equally useful for the project management optic. The experts agreed that there is a practical application of this plan.

The remaining objective of delivering the proposed BIM Execution Plan to the “Comité de normalização BIM”, to work as basis to a technical specification, was attempted by sending emails to the committee in order to expose the template that could assist the AEC firms in the implementation of BIM. However, due to the lack of time for the necessary investigation and changes to the BEP the “Technical specification” is still under development.

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Annexes

Annex 1- Detailed PMBOK processes along with their respective area of knowledge

Legend of the Areas of knowledge of PMBOK

①	Integration Management	⑥	Human Resource Management
②	Scope Management	⑦	Communications Management
③	Time Management	⑧	Risk Management
④	Cost Management	⑨	Procurement Management
⑤	Quality Management	⑩	Stakeholder Management

PMBOK initiating and planning processes along with their respective area of knowledge (adapted from Rita Mulcahy, 2013)

Initiating	
Select project manager	①
Determine company culture and existing systems	①
Collect processes, procedures and historical information	①
Divide large projects into phases	①
Understand the business case	①
Uncover initial requirements, assumptions, risks, constraints and existing agreements	①
Assess project and product feasibility within the given constraints	①
Create measurable objectives	①
Develop project charter	①
Identify stakeholders and determine their expectations, influence and impact	⑩

Planning	
Determine how you will plan for each knowledge area	①②③④⑤⑥⑦⑧⑨⑩
Determine detailed requirements	②
Create project scope statement	②
Assess what to purchase and create procurement documents	⑨
Determine planning team	①⑥
Create WBS and WBS dictionary	②
Create activity list	③⑧
Create network diagram	③⑧
Estimate resource requirements	③⑧
Estimate time and cost	③⑧
Determine critical path	③⑧
Develop schedule	③⑧
Develop budget	④
Determine quality standards, processes and metrics	⑤
Create process improvement plan	①⑤
Determine all roles and responsibilities	①②③④⑤⑥⑦⑧⑨⑩
Plan communications and stakeholder engagement	⑦⑩
Perform risk identification, qualitative and quantitative risk analysis, and risk response planning	⑧
Go back- iterations	①②③④⑤⑥⑦⑧⑨⑩
Finalize procurement documents	①⑨
Create change management plan	①②
Finalize the "how to execute and control" parts of all management plans	①②③④⑤⑥⑦⑧⑨⑩
Develop realistic and final PM plan and performance measurement baseline	①②③④⑤⑥⑦⑧⑨⑩
Gain formal approval of the plan	①②
Hold kickoff meeting	①②

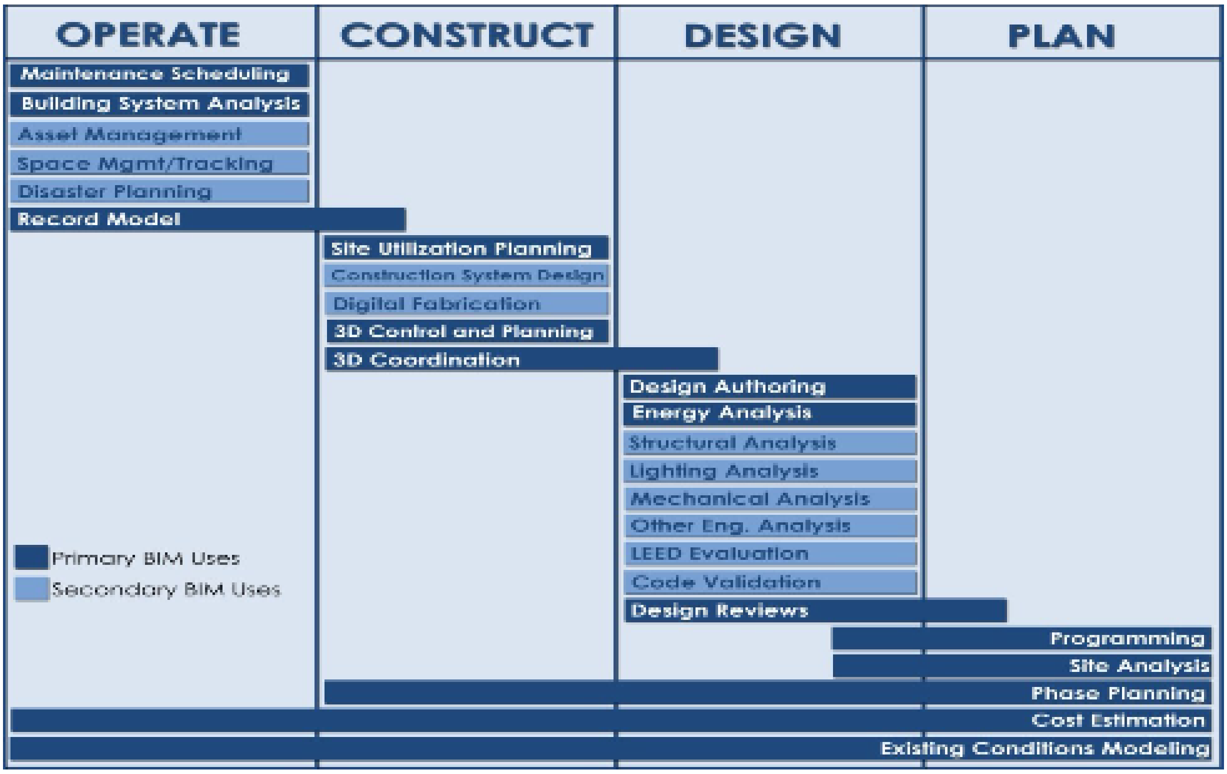
PMBOK Executing, Monitoring and controlling and closing processes along with their respective area of knowledge (adapted from Rita Mulcahy, 2013)

Executing	
Execute the work according to the PM plan	①
Produce product deliverables	①
Gather work performance data	①
Request changes	①⑤⑥⑨⑩
Implement only approved changes	①
Continuously improve	①⑤
Follow processes	①⑤
Determine whether processes are correct and effective	⑤
Perform quality audits	⑤
Acquire final team	⑥
Manage people	⑥
Evaluate team and individual performance	⑥
Hold team-building activities	⑥
Give recognition and rewards	⑥
Use issue logs	⑥
Facilitate conflict resolution	⑥
Release resources as work is completed	⑥
Send and receive information, and solicit feedback	⑦
Report and project performance	⑦
Manage stakeholder engagement and expectations	⑩
Hold meetings	⑦
Select sellers	⑨

Monitoring and controlling	
Take action to control the project	①②③④⑤⑦⑧⑨⑩
Measure performance against the performance measurement baseline	①②③④
Measure performance against other metrics in the PM plan	①②③④⑤⑦⑧⑨⑩
Analyze and evaluate performance	①②③④⑤⑦⑧⑨⑩
Determine if variances warrant a corrective action or other change request	①②③④⑤⑦⑧⑨⑩
Influence the factors that cause changes	①②③④⑤⑦⑧⑨⑩
Request changes	①②③④⑤⑦⑧⑨⑩
Perform integrated change control	①
Approve or reject changes	①
Update the PM plan and project documents	①③④⑦⑨
Inform stakeholders of the results of change request	①⑦⑩
Monitor stakeholders engagement	⑩
Manage configuration	①
Create forecasts	③④
Gain acceptance of interim deliverables from the customer	②
Perform quality control	⑤
Perform risk reassessments and audits	⑧
Manage reserves	⑧
Control procurements	⑨

Closing	
Confirm work is done to requirements	⑨
Complete procurement closure	⑨
Gain final acceptance of the product	①
Complete financial closure	①
Hand off completed product	①
Solicit feedback from the customer about the project	①
Complete final performance reporting	①
Index and archive records	⑨
Gather final lessons learned and update knowledge base	⑨

Annex 2- List of twenty five BIM Uses by phase of the project (CIC, 2011)



Annex 3- BIM Execution Plan Template- Portuguese

1- Descrições e âmbito do projeto

1.1- Cultura das organizações envolvidas

É importante definir a cultura das organizações envolvidas e os sistemas existentes que podem influenciar o projeto durante todo o seu ciclo de vida, para que a equipa do projeto tenha a possibilidade de se adaptar as diferentes situações.

1.2- Missão e âmbito do projeto BIM

A equipa deve definir a razão para a implementação do BIM e como este irá maximizar o valor do projeto, bem como a missão BIM e os principais resultados propostos (o que o projeto pretende alcançar, e a sua importância).

1.3- Critérios de sucesso do projeto

Aferir os critérios que vão determinar se o projeto foi bem desenvolvido e executado. Devem-se definir apropriadamente dois critérios de sucesso do projeto, o primeiro relacionado com o sucesso da gestão de projetos (sucesso em termos de custo, qualidade, etc) e o segundo relacionado com o sucesso do produto completo. Isto porque o projeto pode ser gerido corretamente mas não atingir as expetativas ou fiabilidade desejadas.

1.4- Requisitos BIM e informações de instalação

Expor aqui possíveis acordos, pressupostos iniciais, condicionalismos e como a equipa vai lidar com a sustentabilidade do projeto. A equipa deve recolher e organizar os requisitos do dono de obra e das diferentes partes interessadas, estes requisitos podem incluir exigências sobre qualidade, conformidades, áreas da gestão de projetos como tratamento de riscos, modo de gestão do trabalho ou sobre capacidades ou particularidades que as partes interessadas gostariam de ver no produto.

2- Informações do projeto

2.1- Informações gerais do projeto

A equipa deve documentar as informações gerais do projeto para referência futura.

Dono do projeto	...
Nome do Projeto	...
Localização / Endereço do projeto	...
Tipo de contrato e / ou método de entrega	...
Orçamento do projeto	...
Descrição do Projeto	Tamanho geral, número de edifícios, etc
Informação adicional	Características ou necessidades específicas do projeto
Números do projeto	Número do contrato, número da ordem de tarefa, número do projeto, etc

2.2- Calendário / Prazos do projeto

Devem ser identificadas as fases do projeto, pontos de controlo e os grandes eventos que ocorrerão durante o ciclo de vida do projeto. Também deve existir a indicação se o ponto de controlo é obrigatório, por exemplo se for exigido em contrato, ou opcional, se for baseado em informação histórica.

Fase do projeto / pontos de controlo	Obrigatório (Sim/ Não)	Data de início estimada (AAA-MM-DD)	Data final estimada ((AAA-MM-DD)	Prazo em que o dono do projeto deve ser informado se o trabalho não estiver completo	Partes interessadas envolvidas
Modelagem 3D	Não	2014-12-05	2015-12-05	2016-01-05	Arquiteto, engenheiros
Modelagem Arquitetura					

2.3- Plano de Custos

A equipa deve definir o plano de custo e os seus postos de controlo, bem como os limites de custos em que a decisão deve passar pelas partes interessadas.

Fase do projeto / Pontos de controlo	Custo estimado da atividade (horas da atividade * custo do tempo das partes envolvidas)	% Do orçamento total	Limite de custo em que o dono do projeto deve ser informado	Partes interessadas envolvidas
3D de modelagem	5000 €	12	120% do custo estimado	Arquiteto, engenheiro

2.4- Identificação dos riscos envolvidos no projeto

Avaliação dos principais riscos do projeto, bem como seus possíveis impactos. Incluir riscos genéricos (inerentes à natureza do projeto), riscos específicos (relacionados com a particularidade do projeto) e riscos residuais (riscos remanescentes).

Descrição do risco	Probabilidade de ocorrência (%)	Impacto de risco (1-5)			Medidas de mitigação do risco	Entidade responsável pela gestão de riscos	Frequência da revisão do risco
		Tempo	Custo	Função			
Planeamento inadequado	20	4	4	5	Revisões frequentes ao plano de execução BIM	Autor do plano de execução BIM	Final de cada fase do projeto
Condições climatéricas							

3- Informação sobre as partes interessadas

3.1- Identificação dos líderes BIM e das partes interessadas

Identificação dos líderes BIM de cada especialidade ou utilização e das partes interessadas do projeto.

Posição	Organização	Nome do contato	Abreviatura	Localização	Email	Telefone
Arquiteto	ABC	ABC	Arq	ABC	ABC	123

3.2- Gestão das partes interessadas

A equipa de planeamento deve descrever cada parte interessada, mapeando-o (matriz poder/ interesse) e identificando as suas áreas de interesse ou outra informação particular. Além disso, a equipa deve registrar o nível atual e desejado de envolvimento da parte interessada e enumerar alguns métodos para gerir a parte.

Parte interessada	Descrição da parte interessada	Nível de envolvimento atual da parte interessada	Nível de envolvimento pretendido	Método (s) de gestão da parte interessada
Arquiteto	Posição C na matriz de mapeamento. Especialista na área de risco	Apoiante	Líder	Incorporar o arquiteto com na tomada de decisão sobre os riscos do projeto e mantê-lo integrado no projeto

4- Objetivos do projeto / Usos BIM

4.1- Objetivos principais do projeto BIM

Descrição das principais metas e objetivos do projeto BIM.

Descrição do objetivo	Prioridade (alta/ media/ baixa)	Ações para a implementação do objetivo	Possíveis usos BIM
As-built exato	Alta	Definição dos requisitos para definição do as-built e correta definição dos dados modelo	Execução do projeto Revisão do projeto

4.2- Controlo dos objetivos BIM

A equipa do projeto deve definir os pontos de controlo dos objetivos BIM (por exemplo, no final de cada fase do projeto), e os principais resultados que verificam o seu sucesso.

Objetivo do projeto	Pontos de Verificação / Calendário	Resultados que verificam a realização do objetivo
As-built exato	Fim da fase de projeto	As-built completo e preciso, alcançando todos os requisitos definidos e facilitando a navegação e acesso á informação

4.3- Folha de seleção dos usos BIM

A equipa deve completar a folha de seleção dos usos BIM.

4.4- Identificação dos usos BIM nas diferentes fases do projeto

A equipa deve colocar um “x” ao lado de cada uso BIM identificado no ponto anterior.

X	Planeamento	X	Projeto	X	Construção	X	Operação
	Programação		Execução do Projeto		Planeamento de utilização do espaço		Calendarização da manutenção do edifício
	Análise do Espaço		Revisão de Projeto		Projeto do sistema de Construção		Análise do desempenho do edifício
			Coordenação 3D		Coordenação 3D		Gestão dos bens
			Análise Estrutural		Fabricação digital		Gestão do espaço
			Análise Elétrica		Planeamento e controlo 3D		Planeamento de desastres
			Análise Energética		Registo da modelação		Registo da modelação
			Análise Mecânica				
			Análise de outras especialidades				
			Avaliação da sustentabilidade				
			Validação do Código				
	Planificação das fases		Planificação das fases		Planificação das fases		Planificação das fases
	Estimação de Custos		Estimação de Custos		Estimação de Custos		Estimação de Custos
	Modelação das condições Existentes		Modelação das condições Existentes		Modelação das condições Existentes		Modelação das condições Existentes

5- Posições BIM, responsabilidades e ações de formação

5.1- Descrição de cargos BIM e suas responsabilidades

A equipa deve descrever as principais posições BIM e as suas responsabilidades inerentes. Sendo que algumas posições já estão definidas e a equipa deve modificá-las de acordo com o projeto.

Posição	Principais responsabilidades e autoridade inerente
Gestor da coordenação do projeto	Fornecer o elo de comunicação entre as equipas de projeto e construção. Normalmente eleito pelo dono de obra, este papel integra os resultados do projeto com o programa de construção para garantir a entrega no prazo. Além disso, esta pessoa deve ser responsável pela manutenção de pastas e dos nomes dos ficheiros.
Líder do projeto	Gere o projeto, incluindo o desenvolvimento e aprovação da informação. O líder do projeto confirma as entregas do projeto das equipas, estabelecendo as questões de autoria e de estratégia do espaço. Além disso, é a pessoa responsável pela aprovação da documentação antes de passar para a área "compartilhada" no CDE.
Gestor das equipas de tarefas	Responsável pela produção das entregas do projeto, fazendo cumprir as normalizações. Sendo que geralmente, os projetos são divididos por disciplina, o gestor das equipas de tarefas é o responsável da disciplina, respondendo ao líder do projeto.
Gestor da Interface	O gestor da interface deve ser inserido em cada tarefa, sendo responsável pela negociação da alocação de espaço. Se uma equipa precisa de mais espaço em uma determinada área do projeto, este deve ser discutido com o gestor da interface. Os gestores da interface devem responder aos gestores das equipas de tarefas e ao líder do projeto.
Gestor da informação do projeto	Responsável pela aplicação das normas BIM do projeto e garantir a entrega da informação requeria pelas partes interessadas. O gerente de informações do projeto deve responder ao gestor da coordenação do projeto.
Coordenador CAD	Aplica os padrões BIM e CAD relacionados com o projeto, garantindo que há uma abordagem consistente á modelação do projeto, aos problemas CAD e às metodologias praticadas no projeto. O coordenador do CAD deve responder ao gestor das equipas de tarefas e ao gestor da informação do projeto.
Gestores de construção	Responsável pela análise do local, pela estimativa preliminar, pelo calendário preliminar e pela modelagem 4D.
Engenheiros estruturais	Responsável pelo relatório geotécnico, pelo modelo base preliminar, pela seleção do sistema estrutural, e pelos projetos de estruturas preliminar e final.

5.2- Equipas responsáveis pela implementação dos usos e modelos BIM

A equipa deve selecionar a organização que irá executar cada uso e estimar as horas necessárias para a sua execução.

Uso BIM	Organização	Número de empregados	Horas de trabalho estimadas	Localização (s)	Contato principal
Projeto de autoria	ABC	20	123	ABC	123

A equipa deve identificar os modelos existentes do projeto, bem como o seu conteúdo e organização responsável pela sua criação.

Nome do modelo	Conteúdo geral do modelo	Fase do projeto	Equipa de criação	Software de criação	Contato primário
Modelo de Arq	As-built definido de acordo com as especificações de nível de detalhe	Projeto	Arquiteto	ABC	123

5.3- Ações de formação BIM

Na folha de seleção dos usos BIM foram definidas as competências necessárias para que cada equipa fosse capaz de implementar os usos BIM, no entanto se a equipa não atender as capacidades necessárias devem ser agendadas ações de formação para que possa existir um melhor aproveitamento do BIM. As ações de formação também podem melhorar as competências de software e pessoais, e melhorar o ambiente geral na equipa.

Acão de formação	Aspeto a melhorar	Frequência	Participantes
Formação IFC	Melhor compreensão do modelo de dados IFC, a fim de melhorar as trocas de informações	Uma vez	As partes interessadas que vão receber ou enviar informações

6- Mapeamento de processos BIM

A equipa deve mapear os processos BIM e as atividades do projeto, fornecendo um plano detalhado para a execução de cada uso BIM e as trocas de informações de cada atividade.

6.1- Mapa global de processos

A equipa deve definir o mapa global de processos BIM.

6.2- Mapa detalhado dos usos BIM

Cada parte interessada responsável pela implementação de um uso BIM deve definir o respetivo mapa detalhado do processo.

6.3- Revisão dos mapas

A equipa deve rever os mapas ao longo da implementação do BIM, tanto para clarificar os processos como para refletir sobre os processos realmente utilizados na prática. Como tal a equipa deve definir um calendário de revisão dos mapas de modo a comparar os processos utilizados com os planeados de modo a atualizá-los.

7- Requisitos de trocas de informação

7.1- Folha das trocas de informação

Os elementos do modelo de cada disciplina, nível de detalhe ou quaisquer outros atributos importantes do projeto devem ser documentados usando a folha de trocas de informação. A equipa deve definir qual é a estrutura de divisão dos elementos do modelo e em seguida preencher a folha das trocas de informação, definindo os requisitos mínimos de informação de cada modelo e a sua classificação pela definição LOD.

7.2- Calendarização da entrega do modelo referente às trocas de informação

A equipa deve documentar as trocas de informações que vão ocorrer durante todo o projeto.

Informação trocada	Autor do ficheiro	Recetor do ficheiro	Frequência	Data (AAAA-MM-DD)	Tipo de modelo	Software	Tipo do ficheiro nativo	Tipo de troca de ficheiro
Projeto para análise estrutural	Arch	Engenheiro Estrutural	Uma vez	2016/02/14	Struct	ABC	ABC	IFC

8- Procedimentos de colaboração

8.1- Estratégia de colaboração/ ambiente comum de dados

Descrição de como a equipa vai cooperar. Descrever o ambiente comum de dados, que a equipa deve criar para melhorar a colaboração do projeto BIM.

8.2- Procedimentos de reuniões

A equipa deve definir as reuniões que devem ser levadas a cabo ao longo do projeto, bem como as suas principais características. Alguns exemplos de reuniões já estão definidos.

Reunião	Principais objetivos	Duração estimada	Fase do projeto	Frequência	Participantes	Localização
1	Kick-off (introdução ao BEP) Pontos de controlo	120 minutos	Projeto	Uma vez	Dono de obra, arquiteto, engenheiro (s), gestor de projetos, gestor BIM	
2	Usos BIM Software Gestão do risco	120-180 minutos	Projeto	Uma vez	Dono de obra, arquiteto, engenheiro (s), gestor de projetos, gestor BIM	
3	Revisão do plano BIM	60 minutos	Todas	Por Mês	Dono de obra, arquiteto, engenheiro (s), gestor de projetos, gestor BIM	
4	Gestão das normalizações dos modelos	60 minutos	Projeto	Uma vez	Dono de obra, arquiteto, engenheiro (s), gestor de projetos, coordenador CAD	
5	Nível de detalhe necessário	180 minutos	Projeto	Uma vez	Dono de obra, arquiteto, engenheiro (s), gestor de projetos, gerente de intercâmbio de informação, gestor da informação do projeto	
6	Sign Off (BEP final) Próximos passos	30 minutos	Projeto	Uma vez	Dono de obra, arquiteto, engenheiro (s), gestor de projetos	

8.3- Espaço de trabalho interativo / ambiente comum de dados

A equipa deve descrever o espaço físico e todos os componentes necessários para acomodar a colaboração, comunicação e revisões ao plano BIM. Além disso, se videoconferências forem utlizadas, devem ser considerados fatores como o fuso horário, as implicações de software ou as restrições do país.

8.4- Procedimentos de comunicações eletrónicas

O gestor de modelos deve definir as permissões de acesso aos arquivos e registá-las nesta fase. As permissões podem ser: apenas visualizar (V); modificar a permissão (M); permissão de download (D) ou nenhum acesso permitido (N). Além disso, já são definidos alguns exemplos de como a tabela pode ser preenchida, sendo que as partes interessadas definidas são: o proprietário (O), o arquiteto (A) e o empreiteiro (C).

Estrutura dos ficheiros						Protegido por palavra-chave	Atualizações	Partes interessadas			
						(Sim/ Não)		O	A	C	…
BIM											
	WIP Area										
		CAD									
			Architect CAD Files			No	daily	D	M	M	,,,
			…								
		BIM models									
			…								
		Export data									
			…								
		WIP_TSA									
			…								
	Shared Area										
		CAD									
			Architect CAD Files			No	finished	D	V	V	…
		BIM models									
			…								
		CoordModels									
			…								
	Published Area										
		YYY.MM.DD_Description									
			Submission files								
					…						
	Archived Area										
		YYY.MM.DD_Description									
			Archived files								
					…						
	Incoming										
		Source of data									
			YYY.MM.DD_Description								
				Incoming files							
					…						
	BIM resources										
		Title Blocks									
		Logos									
		BIM standards									
		Presenting styles									

8.5- Lista dos gestores de modelos

Documentar os gestores de modelos e as suas autorizações concedidas quanto ao acesso e distribuição de documentos.

Organização	Disciplina	Nome do gerenciador de Modelo	Email	Autoridade (Upload, download, mudar acesso/ distribuição)
ABC	Estrutural	ABC	ABC	Alterar o acesso

9- Gestão da qualidade

9.1- Arquivos BIM a serem controlados

A equipa deve definir os arquivos BIM a ser controladas e suas instruções de controlo. O COBIM recomenda controlar cinco níveis de extensão e propósito. O COBIM recomenda que o controlo de qualidade envolva cinco níveis de extensão e propósito. Os níveis são expostos na tabela, devendo a equipa definir as instruções de controlo para cada tipo de ficheiro (COBIM já define uma lista de pontos a verificar).

Ficheiros BIM	Instruções de controlo
Inventário BIM	
BIM espacial	
Elementos de edifícios BIM (arquitetura e estruturas)	
Sistemas BIM	
BIM unido	

9.2- Controlos de qualidade

Define a frequência e as verificações a serem realizadas de modo a assegurar a qualidade dos ficheiros do projeto.

Verificação	Definição	Entidade responsável	Software	Frequência
Visual	Assegura que não existe componentes imprevistas e o projeto inicial foi cumprido.			
Interferências	Detetar problemas no modelo das disciplinas quando dois componentes entram em conflito.			
Normalizações	Detetar problemas relacionados com as normalizações BIM e CAD			
Integridade do modelo	Assegura que a integridade do modelo está alinhada com os usos BIM e com os requisitos do cliente, como exposto nas normalizações do modelo.			
Revisão do projeto	Rever se os desenvolvimentos dos modelos estão alinhados com os requisitos do cliente.			

9.3- Indicadores chaves de performance

Indicadores chave devem ser definidos para avaliar e quantificar a eficiência e desempenho do sistema. Os indicadores chave devem ser focados principalmente no progresso do projeto (planeamento, calendarização, etc.), e no acompanhamento do desempenho do próprio sistema.

Indicador-chave	Definição / Referência
% dos requisitos cumpridos perfeitamente	O mínimo geral de requisitos cumpridos sem qualquer não conformidade é de 90%
Revisão de informações documentadas	Revisão de 20% da informação documentada, admitindo um máximo de 5% de erros
Número de conflitos/não conformidades detetadas	O número de conflitos detetados sobre o trabalho em revisão deverá ser menor a 35%, sendo que não poderá existir nenhum que impeça um próximo passo do projeto
Recorrência das não conformidades	Se existir uma grande recorrência de não conformidades é sinal que algo no sistema não está a funcionar bem. Admite-se uma recorrência de 30% das não conformidades tratadas
Estado da aprovação de documentos	Analise dos documentos importantes do sistema, inquirir se existem processos sem documentos ou que sofram demasiadas revisões. Não se admitem processos sem documentação adequada
Número de horas/ homem gastas no projeto	Avaliação da eficiência do sistema através deste parâmetro, com o objetivo de comparar com o mesmo parâmetro sem a utilização do BIM
Progresso dos As-built	Não se admitem atrasos em relação aos tempos definidos

9.4- Precisão e tolerância dos modelos

Os modelos devem ter o tamanho adequado para o projeto, sendo o mais próximo possível da realidade. A equipa deve definir a tolerância e precisão dos modelos.

Fase do projeto	Disciplina	Tolerância
Documentos do projeto	Arquitetura	Preciso até 5% do tamanho real,
Desenhos finais	CM	Preciso até 10% do tamanho real,

9.5- Tratamento de não conformidades

Deve ser desenvolvido um plano de ação para o tratamento de não-conformidades e /ou mudanças necessárias. O plano de ação pode ser especificado para cada indicador chave de desempenho ou para um grupo de não conformidades (menor / maior / crítico). Exemplos já estão definidos.

Tipo de não conformidade	Plano de ação	Prazo limite de resposta ao plano de ação	Parte responsável pelo acompanhamento/implementação do plano de ação
Crítico	Reunião com as entidades responsáveis de modo a perceber a causa e aprovar a melhor ação corretiva. Solicitar mudança		
Maior	Maior controlo na próxima atividade similar		
Menor	Tomar medidas preventivas		
Revisão de informações documentadas	Se erro percentual é maior do que 5%, a equipa do projeto deve rever e reenviar as informações, a fim de não atrasar o andamento do progresso do utilizador dependente das informações		
Condição de aprovação de documentos	Se existirem documentos sem a devida documentação, rever o processo de aprovação de documentos e reenviar as informações		

9.6- Pedido de mudança

A equipa deverá definir o processo de solicitação de mudanças. Estas podem ser de qualquer espécie, quer de não conformidades encontradas, quer de mudanças de modo a haver uma melhor adequação do projeto á realidade (por exemplo: se os objetivos do projeto não estiverem perfeitamente adaptados á realidade encontrada). Um exemplo do processo de solicitação de mudança é apresentado de seguida:

Identificação da necessidade de mudança-> avaliação da mudança-> impato da mudança (tempo, custos, risco) -> preparação e revisão da ordem de mudança (fase de decisão) -> implementação da mudança-> feedback

10- Infraestruturas tecnológicas

10.1- Software

É importante garantir a compatibilidade entre os softwares de criação, revisão e análise de cada uso BIM, e que as habilidades das partes interessadas são suficientes para garantir as entregas BIM.

Uso BIM	Disciplina	Plataforma de software			Versão
		Criação	Revisão	Análise	
Cria	Arco	Aplicação ABC projeto	-	-	Ver.XX

10.2- Computadores / Hardware

As entregas BIM muitas vezes têm os seus requisitos inerentes de hardware. É importante identificá-los e garantir que tanto o criador como o recetor da informação têm infraestruturas poderosas o suficiente para atender a esses requisitos.

Uso BIM	Hardware	Proprietário do Hardware	Especificações
Execução do projeto	ABC	Engenheiro A	Processador, memória de armazenamento, placa gráfica, etc

11- Estrutura do modelo

11.1- Estrutura de pastas

A equipa deve definir a estrutura das pastas do projeto BIM. A estrutura recomendada é representada nesta fase.

- ***[Project Folder]***
- BIM [BIM data repository]

- **01-WIP [WIP data repository]**
  - CAD [CAD files (incl. 'Modified')]
  - BIM [Design models (incl. 'Modified')]
  - SheetFiles [Sheet/dwg files]
  - Export [Export data e.g. gbXML or images]
  - Families [Components created during this project]
  - WIP_TSA [WIP Temporary Shared Area (TSA)]
- **02-Shared [Verified Shared data]**
  - CAD [CAD data/output files]
  - BIM [Design models]
  - CoordModels [Compilation models]
- **03-Published [Published Data]**
  - YYYYMMDD-Description [Sample submission folder]
- **04-Archived [Archived Data repository]**
  - YYMMDD-Description [Archive folder]
- **05-Incoming [Incoming Data repository]**
  - Source [Data originator]
    - YYYYMMDD-Description [Incoming folder]
- **06-Resource [Project BIM Resources Library]**
  - Titleblocks [Drawing borders/titleblocks]
  - Logos [Project logos]
  - Standards [Project standards]

11.2- Estrutura de nomes dos ficheiros

A equipa deve definir a estrutura dos nomes dos ficheiros. O procedimento recomendado prende-se em seguir as especificações definidas no BS1192:2007 e no AEC (UK) BIM Protocol v2.0 2012 e descrita neste ponto.

[Projeto]-[Originador]-[Zona]-[Nível]-[Tipo de ficheiro]-[Disciplina-[Numero]

11.3- Estrutura do modelo

Como os projetos BIM tendem a ter um tamanho considerável, muitas vezes é exigida a segregação dos dados em partes manegáveis. Assim a equipa deve definir a forma como o modelo será separado, o que pode ser feita de várias formas: por exemplo por edifício, por andar, por áreas, e/ou por disciplina.

11.4- Sistemas de medição e de coordenadas

Inclui por exemplo as escalas e unidades utilizadas, as referências para localização (por exemplo: norte verdadeiro), e o sistema de coordenadas.

11.5- Normalizações BIM e CAD

As normalizações BIM e CAD devem ser identificadas e acordadas, de modo a que possam servir para referência futura.

Normalização	Versão	Usos BIM aplicáveis	Organizações relevantes
Euro código	Xxx	Análise estrutural	Engenharia estrutural

12- Entregas do projeto

Devem ser identificas e discriminadas todas as entregas do projeto.

Item BIM submetido	Criador	Utilizador	Fase	Data de entrega (aproximada)	Formato	Notas
Modelo as-built	Arcq	Engenheiro civil A	Projeto	2016/02/17	ABC	Ver a folha das trocas de informação para garantir que o mínimo de informação requisitada está no modelo

Annex 4- BIM Execution Plan Template- English

1- Overview and scope of the project

1.1- Culture of the involved organizations

It is important to define the enterprise culture and existing systems that can influence the project throughout its life cycle so that the project team can adapt to different situations.

1.2- BIM Mission and scope of the project

The team must define the reason for the use of BIM and how it will maximize the value of the project, as well as its mission and major proposed results (what the project aims to achieve, and its importance).

1.3- Project success criteria

Determine the criteria that will regulate if the project was well developed and executed. There should be defined two concepts of project success: the first is the project management success which focuses upon the project process and in the accomplishment of cost, time, and quality objectives; the second refers to the product success which deals with the effects of the project´s final product. This is important because a project can be managed successfully but may not meet the costumer or organizational expectations.

1.4- BIM Requirements and Installation information

Expose here possible agreements, initial assumptions, constraints and how to deal with the sustainability of the project. The team should collect the owner and the stakeholders' needs and requirements for the BIM project, these requirements may include requirements about quality, compliance, project management requests, about how the work is managed or capabilities that the stakeholders would like to see on the product.

1.5- BIM Execution Plan structure

The BIM execution plan structure should cover the following parameters: project information; stakeholders information; BIM goals/uses; BIM profiles; responsibilities and training activities; BIM processes mapping; information exchanges requirements; collaborative procedures, quality management; technological infrastructure; model structure; deliverables of the project; that are defined and are in tables to be filled by the coordinator of the implementation of this plan. For better understanding, each table is filled with one or two examples.

2- Project Information

2.1- General Project Information

The team should document the general project information for future reference. Whenever possible, the team should consider standardized classified information.

Project owner	...
Project name	...
Location/Address of the project	...
Project type	...
Contract type/delivery method	...
Project budget	...
Project description	General size, number of buildings, etc
Additional information	Unique project characteristics or requirements of the project
Project numbers	Contract number, task order number, project number

2.2- Calendar/Deadlines of the project

There should be identified the project phases/milestones, and the major events that will occur during the project lifecycle. In addition there should be an indication whether the milestone is mandatory, such as those required by contract, or optional such as those based upon historical information.

Project phase/Milestones	Mandatory (Yes/ No)	Estimated start date (YYY-MM-DD)	Estimated end date (YYY-MM-DD)	Deadline at which the project owner should be informed, if work is not completed	Stakeholders involved
3D modelling-Volumetric study	No	2014-12-05	2015-12-05	2016-01-05	Architect, engineer
3D modelling-LOD 3	Yes				
(…)					

2.3- Cost Plan

The team should define the cost plan and its checkpoints, as well as the costs limits to which the decision should pass by the stakeholders.

Project phase/Milestones	Estimated activity cost (activity hours * stakeholder time cost)	% of total budget	Cost limit at which the project owner should be informed	Stakeholders involved
3D Modelling	€	12	110% of estimated cost	Architect, engineer
(...)				

2.4- Identification of risks involved in the project

Evaluation of the major project risks, as well as their possible impacts. Include generic risks (inherent to the nature of the project), specific risks (relating to the particularity of the project) and residual risks (remaining risks).

Description of the risk	Probability of occurrence (%)	Risk impact (1-5)			Risk Mitigation measures	Entity responsible for the risk management	Frequency of risk Review
		Time	Cost	Function			
Inadequate planning	20	4	4	5	Frequent revisions to BIM execution plan	BIM execution plan author	End of every phase of the project
(...)							

3- Stakeholders information

3.1- BIM leads and stakeholders identification

Identification of the stakeholders and BIM leads of each specialty or use.

Position	Organization	Contact name	Abbreviation	Location	Email	Phone
Architect	ABC	ABC	Arc	ABC	ABC	123
(...)						

3.2- Stakeholders management

The planning team should describe each stakeholder by mapping him (power/interest matrix) and identifying their areas of interest or other particular information. In addition the team should register the current and desired level of engagement of the stakeholder and enumerate some methods to manage him.

Stakeholder	Stakeholder description	Current engagement level of the stakeholder	Desired engagement level	Method (s) of managing the stakeholder
Architect	Position C at the mapping matrix. Expert at risk area	Supportive	Leading	Incorporate the architect at the planning risk decision and keep him integrated on the project
Investor	Position D at the mapping matrix Supports with large funding the project, but exerts lots of pressure	Leading	Leading	Inform the investor of all major steps of the project, involving him at the project meetings and keeping him constantly informed about the deadlines and costs achievement
(...)				

4- Project goals/BIM Uses

4.1- Main BIM goals

Description of the main BIM goals and objectives.

Goal description	Priority (High /medium/ low)	Actions for the goal implementation	Possible BIM uses
Exact as-built	High	Definition of the requirements of the as-built and correct definition of the model data	Facilites management
(...)			

4.2- BIM goals control

The project team should define the BIM goals checkpoints (for example at the end of each project phase), and the main results to verify their success.

Project Goal	Checkpoints/Timeframe	Results that verify the goal achievement
Exact as built	End of design phase	The as-built is complete and precise, achieving all the defined requirements and facilitating the navigation and access to the information
(...)		

4.3- BIM uses Selection Worksheet

The team should complete the BIM uses Selection Worksheet and put an “x” next to the BIM Uses identified by the team in the previous point.

X	Planning	X	Design	X	Construction	X	Operation
	programming		design authoring		site utilization planning		building maintenance scheduling
	site analysis		design reviews		construction system design		building system analysis
			3d coordination		3d coordination		asset management
			structural analysis		digital fabrication		space management / tracking
			lighting analysis		3d control and planning		disaster planning
			energy analysis		record modeling		record modeling
			mechanical analysis				
			other eng. analysis				
			sustainability evaluation				
			code validation				
	phase planning (4d modeling)		phase planning (4d modeling)		phase planning (4d modeling)		phase planning (4d modeling)
	cost estimation		cost estimation		cost estimation		cost estimation
	existing conditions modeling		existing conditions modeling		existing conditions modeling		existing conditions modeling

5- BIM Positions, responsibilities and training actions

5.1- Description of BIM positions and their responsibilities

The team should describe the main BIM positions and their inherent responsibilities. Some positions are already defined and the team should modify them according with the project.

Position	Main responsibilities and inherent Authority
Design coordination manager	Provide the communication link between the design and construction teams. Usually provided by the contractor this role integrates the design deliverables against the construction program to ensure a delivery on schedule. In addition this person should be responsible for the folder maintenance and file naming.
Lead designer	Manages the design, including information development and approvals. The lead designer confirms the design deliverables of the team and establishes the zone strategy and ownership. In addition is the person responsible for approving the documentation before it passes to the “shared” area in the CDE.
Task team manager	Responsible for the production of design outputs, enforcing the documents standards. Being that usually the designs are divided by discipline, the task team manager is the disciple head, responding to the lead designer.
Interface manager	The interface manager should be appointed for each task and it is his responsibility to negotiate the space allocation. If a team needs more space in a certain area of the design it should be discussed with the interface manager. The interface managers should answer to the task team manage and to the lead designer.
Project information manager	Responsible for enforcing the project BIM standards and ensure delivery of the Stakeholders´ information requirements. The project information manager should respond to the design coordination manager.
CAD coordinator	Enforces the CAD related project BIM standards, and ensures that there is a consistent approach to project modeling and CAD issues and practices throughout the project. The CAD coordinator should be responsible to the task team manager and the project information manager.
Construction managers	Responsible for the site investigation, constructability input, preliminary estimate, preliminary schedule and 4D modeling
(...)	

5.2- Responsible teams for carrying out the uses and BIM models

The team must select the organization that will perform each use and estimate the necessary hours to its execution.

BIM Use	Organization	Number of employees	Estimated work hours	Location (s)	Primary contact
Design authoring	ABC	20	123	ABC	123
(...)					

The team should identify the existing project models, as well as their contents and responsible organization.

Model name	General content of the model	Project phase	Authoring Team	Creation software	Primary Contact
Arc model	As-built defined according with the LOD specifications	Design	Architect	ABC	123
(...)					

5.3- BIM training actions

On the BIM uses Selection Worksheet there were defined the competences of each team to perform the BIM uses, however if the team doesn't meet the necessary capabilities there must be scheduled training actions so that it is taken full advantage of BIM. In addition the training actions can also improve other attributes such as software and personal skills, or improve the overall team environment.

Training action	Aspect to improve	Frequency	Participants
IFC formation	Better comprehension to the IFC data model in order of improving the information exchanges	One time	Stakeholders that are going to receive or send information
(...)			

6- BIM process mapping

The team should map the project processes and activities, providing a detailed plan for the implementation of each use BIM and the information exchanges of each activity.

6.1- BIM overview process map

The team should define the BIM process overview map.

6.2- Detailed BIM Uses process map

Each stakeholder responsible for the implementation of a BIM use should define the respective process map.

6.3- Maps review

The team should review the maps along the implementation of BIM, both to clarify the processes as to reflect on the processes actually used in practice. As such the team should set a schedule for the maps review in order to compare the processes used with the planned in order to update them and take lessons.

7- Information exchanges requirements

7.1- BIM information exchange requirements worksheet

The model elements by discipline, level of detail or any important attributes of the project are documented using the information exchange worksheet. The team should define what the model element breakdown structure is and then fill the BIM information exchange requirements worksheet by defining the minimum information requirements of each model and its classification by the LOD definition.

BIM Use Title	Programming
Project Phase	Planning
Type of Information Exchange (Input/output)	
Time of Exchange (SD, DD, CD, Construction)	
BIM model(s) involved	
Receiver File Format (example: IFC)	
Application & Version (Example: Autocad 2013)	

Model Element Breakdown- CSI Uniformat 2010		Model element (3D) included (Yes/No)	Model element (2D) included (Yes/No)	Data only (Specs) (Yes/No)	LOD	Model element author (MEA)	Notes
A	Substructure						
A10	Foundations						
A1010	Standard Foundations						
A1010.10	Wall Foundations						
(…)							

7.2- Model Delivery Schedule of Information Exchanges

The team should document the information exchanges that are going to occur throughout the project.

Information exchange	File sender	File Receiver	Level of development	Frequency	Date (YYYY-MM-DD)	Model file	Software	Native file type	File exchange type
Design authoring to structural analysis	Arc	Structural Engineer	LOD 200	One time	2016-02-14	Struct	ABC	ABC	IFC
(...)									

8- Collaboration procedures

8.1- Collaboration strategy/ common data environment

Description of how the team will cooperate. Describe the common data environment that the team should create to improve the collaboration of the BIM project.

8.2- Meeting Procedures

The team must define the meetings that should be carried out throughout the project, as well as their main characteristics. Some examples of reunions are already defined.

Meeting	Main objectives	Estimated duration	Phase of the project	Frequency	Participants	Location
1	Kick-off (introduction to BEP) Team milestones	120 minutes	Project	One time	Owner, architect, engineer (s), project manager, BIM manager	
2	BIM uses Software Risk management	120-180 minutes	Project	One time	Owner, architect, engineer (s), project manager, BIM manager	
3	BIM Plan Review	60 minutes	All	Monthly	Owner, architect, engineer (s), project manager, BIM manager	
4	Standards model management	60 minutes	Project	One time	Owner, architect, engineer (s), project manager, CAD coordinator	
5	Level of development	180 minutes	Project	One time	Owner, architect, engineer (s), project manager, information exchanges manager, project information manager	
6	Sign Off (Final BEP) Next steps	30 minutes	Project	One time	Owner, architect, engineer (s), project manager	
(...)						

8.3- Interactive workspace/common data Environment

Describe the physical space and all the components to accommodate the necessary collaboration, communication and reviews to the BIM plan. In addition if video conferences are considered there should be considered factors like time zone, software implications or country restrictions.

8.4- Electronic communications Procedures

The model manager(s) should define the access permissions to the files and register them at this phase. The permissions can: view permission (V); modify permission (M); download permission (D) or no access permitted (N). In addition there are defined some examples of how the table can be filled, being that the stakeholders defined are the owner (O), the architect (A), the contractor (C).

File Structure						Password protected	Updates	Project Stakeholders			
						(Yes/ No)		O	A	C	…
BIM											
	WIP Area										
		CAD									
			Architect CAD files			No	Daily	D	M	M	,,,
			…								
		BIM									
			…								
		Sheet files									
			…								
		Export									
			…								
		Families									
			…								
		WIP_TSA									
			…								
	Shared Area										
		CAD									
			Architect CAD files			No	Finished	D	V	V	…
		BIM									
			…								
		CoordModels									
			…								
	Published Area										
		YYY.MM.DD_Description									
			Submission files								
					…						
	Archived Area										
		YYY.MM.DD_Description									
			Archived files								
					…						
	Incoming										
		Source of data									
			YYY.MM.DD_Description								
				Incoming files							
					…						
	Resources										
		Title Blocks									
		Logos									
		Standards									

Note: at the table presented there are already defined some examples of how the table can be filled, being that the defined stakeholders are: the owner (O), the architect (A) and the contractor (C).

8.5- List of the model managers

Document the model managers and their security, access and distribution of documents accorded authorizations.

Organization	Discipline	Model manager name	Email	Type of authority (Upload, download, change access/distribution)
ABC	Structure	ABC	ABC	Change access
(...)				

9- Quality management

9.1- BIM Files to be controlled

The team should define the BIM files to be controlled and their control instructions. The proposed method of control of this guide is based on the COBIM v1.0 2012 ("quality assurance"), which defines five level of extent and purpose to be verified. To control the files this guide suggests that the planning team defines a quality checklist, being that the COBIM v1.0 2012 ("quality assurance") already defines checklists for the BIM files, which are to be consulted and modified for the project incorporating the acceptance criteria defined.

BIM Files	Description	Control instructions
Inventory BIM	Documentation of the starting situation for renovation construction (example: Spaces and building elements of the existing buildings)	
Spatial BIM	Design of the BIM spaces (example: space objects, building envelope)	
Building element BIM (architectural and structural BIM)	Building elements defined in a Building Element BIM (example: frame structures, foundations)	
System BIM	BIM systems (example: mechanical, electrical and plumbing system BIM)	
Merged BIM	A BIM merged from the BIMs of different domains of design, making possible to review them together to investigate their compatibility	

9.2- Quality control Checks

Define the control checks to be carried out in order to ensure the quality of the project and their frequency.

Verification	Definition	Responsible entity	Software	Frequency
Visual	See that there are no unintended model components and the design intent has been followed			
Interference	Detect problems in the disciplines model where two components are clashing including soft and hard			
Standards	Ensure that the BIM Standard have been followed			
Model Integrity	Ensure integrity of the model aligns with BIM Uses and client's BIM specific modeling and documentation requirements and standards, as set out in Model Standards.			
Design review	Review that the ongoing development of the model is aligned with the client objectives			

9.3- Key performance Indicators

Key indicators should be defined to evaluate and quantify the efficiency and performance of the system. The key indicators should be mainly focused in the progress of the project (planning, calendars, etc.), and in monitoring the performance of the processes used.

Key Indicator	Definition/Reference
% Of requirements met perfectly	The minimum general requirements met perfectly is of 90%
Review of documented information	Review of 20% of the documented information, admitting a maximum of 5% of errors
Number of conflicts/nonconformities detected	The number of nonconformities detected at work in revision should be less than 35 %, but none that prevents the next step of the project
Recurrence of non conformities	If there is a large recurrence of non-conformities something in the system is not working well. It is admitted a recurrence of 30% of non-conformities treated
Condition of approval of documents	Review of important documents of the system, investigate whether there are processes without documents or who suffer from too many revisions. Do not admit processes without proper documentation
Number of man hours spent on the project	Evaluation of the efficiency of the BIM system through this parameter, with the objective of comparing with the same parameter without the use of BIM
Progress of The as-built drawings	Do not admit delays in relation to the times defined
(…)	

9.4- Model accuracy and tolerance

The team should define the model accuracy and the admitted tolerance. Models should include all appropriate dimensioning as needed for design intent, analysis, and construction.

Project phase	Discipline	Tolerance
Design documents	Architecture	Accurate up to 5% of the real size
Shop drawings	CM	Accurate up to 10% of the real size
(…)		

9.5- Tratamento de não conformidades

It should be developed an action plan for treatment of non-conformities and/or necessary changes. The action plan can be specified for each key performance indicator or to the group nonconformities (minor/ major/ critical). Examples are already defined.

Type of nonconformity	Action plan	Deadline for response to the action plan	Responsible party for monitoring/implementation of the action plan
Critical	Meeting with the responsible entity in order to understand the cause and approve the best corrective action. Change request		
Major	Greater control at the next similar activity		
Minor	Take preventive measures		
Review of documented information	If percent error is greater than 5%, project team is to revise and resubmit information, as to not delay downstream user progress		
Condition of approval of documents	If there are documents without proper documentation, review the process of the approval of documents and resubmit information		
(…)			

9.6- Change request

The team should define the change request process. These can be used to adapt to non-conformities encountered or to give a better adaptation of the project to reality (for example: objectives and goals not perfectly adapted). An example of the change request process is presented below:

Identification of the need for change-> change-> evaluation impact of change (time, costs, risk)-> preparation and revision of the change order (decision phase)-> change-> implementation feedback

10- Technological infrastructures

10.1- Software

It is important to ensure compatibility between the author, review and analysis software of each BIM Model, and that the skills of the stakeholders are sufficient to ensure the BIM deliveries.

BIM Use	Discipline	Software platform			Version
		Author	Review	Analysis	
Design authoring	Arc	ABC Design application	ABC Review application	ABC Analysis application	Ver.xx
(...)					

10.2- Computers/Hardware

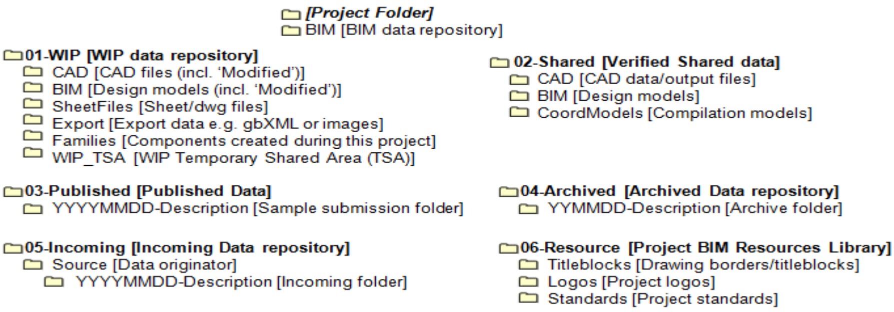
BIM deliveries often have their inherent requirements of hardware. It is important to identify them and ensure that both the author and the receiver of information have infrastructure powerful enough to meet these requirements.

BIM Use	Hardware	Hardware owner	Specifications
Design authoring	ABC	Engineer A	Processor, memory storage, graphic, etc
(....)			

11- Model structure

11.1- Folder structure

The team should define the folder structure for the BIM project. The recommended structure is represented at this phase.



11.2- File naming structure

The team should define the file naming structure. The procedure recommended is to follow the specifications defined on BS1192:2007 and on AEC (UK) BIM Protocol v2.0 2012 and described below.

[Project]- [Originator]-[Zone]-[Level]-[File Type]-[Discipline-[Number]

11.3- Model structure

As the BIM projects tend to have a considerable size, they often require the segregation of data into manageable sized pieces. Taking that into account the team should define how the model will be separated, which can be made by various forms, for example by building, by floors, by zones, by areas, and/or by disciplines.

11.4- Measurement and coordinate systems

Includes the scales and units used, location references (for example: True North), and the coordinate system.

11.5- BIM and CAD standards

The items such BIM and Cad standards should be identified and agreed upon, to serve as future reference.

Standard	Version	BIM uses applicable	Relevant organizations
EuroCode	Xxx	Structural analysis	Structure engineers
(....)			

12- Project deliverables

The project deliverables should be identified and described.

BIM submitted item	Author	User	Phase	Delivery date (approximated)	Format	Notes
As-Built Model	Arc	Civil engineer A	Design	2016-02-17	ABC	See information exchange worksheet to ensure that the minimum information required is in the model
(…)						