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BIM EXECUTION PLAN, MATURITY AND DIFFUSION POLICIES APPLIED TO SUSTAINABLE DESIGN OF STRUCTURES

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Abstract

Gradually, some of the companies in the Architecture, Engineering, Construction and Operation (AECO) sector have been implementing the BIM (Building Information Modelling) methodology, adapting the way they work and trying to systematize procedures. BIM is based on a concept of connectivity of parametric objects with different dimensions, evolving over time and collaboratively manipulated by different agents in the different phases of the life cycle of a construction asset. Thus, it is legitimate to state that, the range of variables and the complexity of the connections, does not allow to neglect the way in which a BIM solution is implemented. Thus, it becomes evident that the implementation of BIM must be planned, and to respond to the planning needs of a given project in BIM, BIM Execution Plans (BEP) have been developed. BEP must be aligned with each phase of the project and define: i) the strategic, tactical and operational objectives; ii) the modes of collaboration between the different actors; iii) the information sharing; iv) the roles and responsibilities of the stakeholders; v) the software to be used; vi) the Level of Development (LOD); vii) the Level of Information Needed; viii) the quality control procedures; ix) the composition of objects and nomenclature conventions, for a specific project and / or phase of construction project.

This publication addresses the maturity of BIM and its dissemination policies, and aims to present a specific proposal for a BEP applied to structural design offices. In fact, the training of designers for these methodologies, as well as the realization of a BEP, is essential to support all company employees, and / or external, involved in each project. The realization of a BEP allows to systematize the processes involved in the project, increasing the BIM maturity level of the organization.

1. INTRODUCTION

Portugal, like many countries, still does not have the Building Information Modelling (BIM) methodology implemented in most of its companies in the Architecture, Engineering, Construction and Operation (AECO) sector. The lack of national standardization and good practice guides are some of the reasons why this methodology is not yet applied and widespread in most companies in the sector. The bases of the BIM methodology do not yet appear as a requirement for public projects, being only a requirement for some reference projects. Gradually, some of the companies in the sector have been implementing the BIM methodology, adapting their way of working and trying to systematize procedures within the companies themselves. Thus, training employees for these methodologies as well as carrying out a BIM Execution Plan (BEP) is essential to support all company and / or external employees involved in each project. The realization of a BEP allows to systematize the processes involved in the project, increasing the organization's BIM maturity level.

2. BIM MATURITY

BIM maturity refers to the degree of BIM use at the level of an organization or a country. In many countries, such as Portugal, this methodology is still little used in most companies in the AECO sector. However, there are already some companies that invest in this innovation, developing training actions for their employees, to implement these new technologies in projects, even though they are sometimes not a requirement [8]. BIM maturity reflects the level of quality, repeatability and degree of excellence within each BIM capability. BIM capacity is understood to be the resources, competence and experience existing in a particular country or organization. The greater the degree of maturity, the greater the domain of the BIM methodology. Generically, 4 (four) levels of BIM maturity are considered (Figure 1): i) Level 0, pre-BIM; ii) Level 1, modelling; iii) Level 2, collaboration; iv) Level 3, integration (Figure 1).

In the current scenario, it is considered that, in Portugal, in design offices, there are already many cases of software adoption in projects compatible with BIM methodology, exchanges of three-dimensional models between specialties and parameterization of 3D models. Considering the above, it is assumed that the corresponding Maturity Level is between Level 1 and Level 2 (modelling - collaboration), where only project offices that include various specialties can sometimes fully integrate Level 2. Application of BIM concepts is still limited in most companies, so the coordination of different specialties is still a time-consuming process. The coordination of different specialties between different companies is, even more, a more complicated process to manage and always keep up to date.

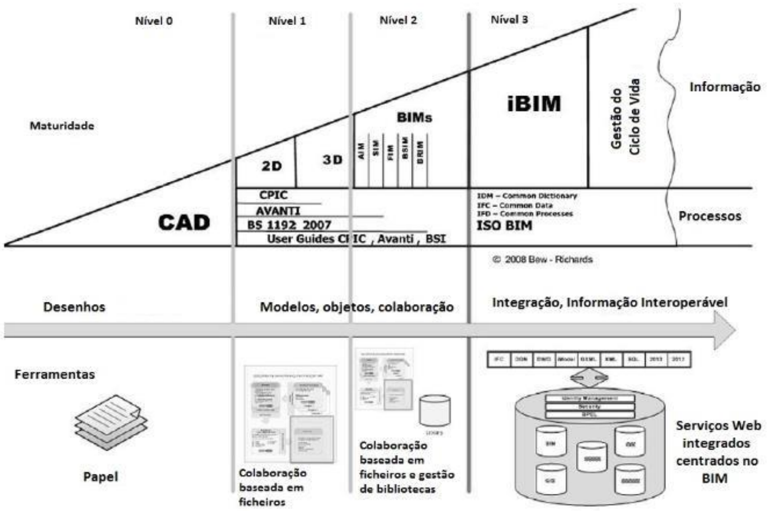

Figure 1. BIM maturity levels

3. BIM STRATEGY, IMPLEMENTATION AND POLICIES

The adoption of these concepts underlying the BIM methodology, associated with the centralization of information from the various specialties in a single model, presupposes a paradigm shift in the traditional industry. The evolution to Industry 4.0 implies a strategic change both in terms of production systems and in terms of business models and implementation. When implementing these methodologies, companies must have a sense of the evolution of this methodology, following (and participating) in work groups oriented towards the evolution of the BIM concept, such as the Technical Committee CT-197 (CT-197) and the Group of BIM work of the Portuguese Technological Platform for Construction (GT-BIM).

The customer is one of the main agents of change, concerning BIM implementation. In many countries, the government is primarily responsible for implementing BIM through the mandatory use of this methodology in all public works. There are already some clients that demand the presentation of projects based on BIM, putting aside all entities that do not comply with this requirement. Factors such as this, encourage change in the construction industry, giving rise to the need for companies to re-qualify themselves to be able to respond to the challenges that are imposed. As mentioned before, cultural and organizational change is a complex challenge that requires a large initial investment and a great capacity to adapt. The adoption of the BIM methodology is preceded by a diffusion process, that leads to the point of adoption, by an organization, certain tools and processes for an object-based collaborative modelling. BIM diffusion means the propagation of BIM processes in a specific group. After a period of planning and preparation through diffusion, it becomes possible to reach a BIM capacity and a certain maturity. It should be noted that the indicated evolutions will always have to be preceded by an investment in software resources and training of human resources [10-11].

The existence of two types of diffusion models for the adoption of a technology and / or methodology is considered, in a more restricted scope (for example, a group of users with certain similar characteristics) [12]: i) the epidemic model; and ii) the Probit model. The epidemic model is based on the diffusion of technology, on the fact that the population is aware of its existence and its benefits, and on the spread of its use through communication between individuals. The Probit Model is based on the effect of individual decision-making on technology diffusion, a decision that is influenced by several factors: i) contagion from a partner who has already adopted the new technology; ii) by the social level that represents the occasion when an individual adopts the technological innovation, when enough similar individuals also adopt; and iii) by social learning. The diffusion of the BIM methodology is more complex to analyse, since BIM is not a simple technological solution, but rather a combined diffusion of new processes, work schemes and technologies [13]. When considering a broader scope, for example a given market or country, it is assumed that the application and dissemination of BIM can be based on five models [14].

i) Model A clarifies how BIM technologies, processes and policies interact with the BIM capability phases, creating nine areas (technology integration, process integration, policy integration, technology collaboration, process collaboration, policy collaboration, technology modelling, process modelling, and policy modelling) for analysis and planning of BIM diffusion, which can be used independently or collectively.

ii) Model B derives from the component maturity analysis, and through this model it is possible to measure and define the BIM maturity of large organizations or countries, allowing the analysis of each of the components using specialized measures applied to that same component. This model allows the identification of the BIM areas that each actor will have to deal with (goals, stages, and milestones to be achieved; advocates and drivers; regulatory framework; outstanding publications; learning and education; benchmark measures and benchmarks; standardized and deliverable parts; infrastructures technologies).

iii) Model C is related to diffusion dynamics and makes it possible to analyse how diffusion starts and from which actors, considering three diffusion dynamics: i) from top to bottom (top-down); ii) from bottom to top (bottom-up); and iii) from the middle (middle-out). The first dynamic characterizes implementation through the imposition of regulations by authorities, which thus influence market organizations to implement innovative technology. The bottom-up dynamic derives from learning through the use and practice of innovative technologies by small organizations. This dynamic slows down the process of adopting the new technology, but it becomes more effective for the adoption of new management processes, and for dealing with any resistance to change. The third dynamic, starting from the middle, is characterized by implementation through large organizations or industry associations, followed by diffusion to small organizations further down the supply chain, which are under pressure to implement innovative technology, by contagion or by imposition, to work with these large organizations or associations, and to the government entities above, for pressure to create regulations regarding innovative technology [15].

iv) Model D characterizes the policies taken to promote the implementation of technologies and / or methodologies. It identifies three implementation activities (communicating, undertaking, and monitoring), which can then take passive, active or assertive approaches depending on the intensity of the policy maker in stimulating the adoption of the technology. Nine policy actions (encourage, educate, prescribe, encourage, encourage, force, observe, follow, control) are identified and the relationships between them represented, and these actions can then be subdivided into smaller policy actions. This model can be used to structure intervention policy or as a diagnostic tool to compare different actions in different countries or markets.

v) Model E characterizes the responsibilities in diffusion of industry players. This model identifies nine BIM actors (policy makers, education institutions, building organizations, individual practitioners, industry associations, communities of practitioners, technology creators, technology advocates, technology service providers) spread across three BIM areas (policies, process, technology). This model can be used to compare the activities related to BIM diffusion carried out by an actor against other actors within the same group or other market groups, or it can be used to compare the BIM diffusion activities of the same actor in different countries. These models are a tool designed to make a solid assessment of BIM diffusion at large scales and support the development of specific policies for the adoption of BIM [14].

4. BIM EXECUTION PLAN

The BEP is a specific document for each project, that defines the objectives and goals to be achieved, protocols for using modelling tools, collaborative processes between participants, among other essential aspects for the correct use of BIM applications. The BEP intends to centralize the information of all project stakeholders, outline the objectives and goals to be met, as well as the guidelines for each isolated BIM use and how they blend to form the project's final product. It also defines the types of software to be used, as well as the types of parts to be delivered. Delivery dates may also be present in the BEP [1-5]. The objective of BEP is essentially to define and reconcile the contributions of the various parties involved in the development of the models during the various phases of the project, thus being the reference document for the regulation and registration of activities related to the BIM project. An objective and well-structured BEP, understood by all entities involved in the project, improves the process of implementing the BIM methodology. The existence of a document such as the BEP should stimulate planning and communication between all entities involved in the project, throughout its execution period. For each project, a BEP must be created, adjusted to its scope and objectives, as well as to the capacities of the member teams [6-7].

To achieve the Objectives and Uses of the BIM Methodology application and considering the requirements / indications of the Owner of Work defined in the specifications, in the case of a Public or Private Customer, it will be necessary to define the BEP in advance, as referred to by several authors. Internationally, several BIM execution plans have been developed and are currently in force in multiple countries, including the CIC “BIM Project Execution Planning Guide” [1], the AEC (UK) “BIM Protocol Project BIM Execution Plan” [2], the Singapore “BIM Essential Guide For BIM Execution Plan” [3], the MIT “Design Standards BIM Execution Plan” [4] and the University of South Florida “BIM Project Execution Plan Template” [5]. After a comparative analysis of the various BEP, several aspects have been found that are transversal to all of them. It is also mentioned that another document, the “BIM Project Execution Planning Guide” from Penn State University, presents a procedure for the creation and implementation of a BEP, consisting of 4 distinct phases: i) Identify the objectives and applications of BIM in the project; ii) mapping processes of an integrated BIM project; iii) identify information exchanges; and iv) define infrastructure to support the implementation of BIM. The Penn State University “BIM Project Execution Planning Guide” presents in its Annex G, a typical structure to be applied to a BEP. However, it should be noted that the model presented must be adapted to the type of project and the BIM requirements it presents, and the information suggested in this annex may be adjusted by adding or removing chapters [8-9].

5. APPLICATION TO SUSTAINABLE DESIGN OF STRUCTURES

To define a BEP proposal for design offices, a practical case of carrying out a project for a building with residential use is described below. The specialties that will constitute the project are: i) architecture; ii) stability; iii) water supply network (including DHW); iv) sewage and rainwater network; v) electrical installations; vi) telecommunications infrastructure (including sound); vii) fire safety in buildings; viii) electronic security (CCTV, Intrusion and Access Control); ix) air conditioning, ventilation and smoke exhaust; x) gas installation; xi) electromechanical vertical transport installations; and xii) study of thermal behaviour and study of acoustic conditioning. It should be noted that the management of all specialties and the respective teams affected is a very demanding task and one that grows with the complexity of the project. It should also be noted that usually the Work Owners request the delivery of studies in a phased manner (Preliminary Study, Base Project, Execution Project and Technical Assistance already under construction). Any study is an iterative / evolutionary process with great information / communication management, between all the participants in the project, and that the interaction between them will be intensely linked to the quality of the final product [16-18]. Given this scenario of interaction between the different teams, methodologies that minimize errors or omissions are justified, allowing for improved communication between project teams, with the goal of improving quality and greater control over future construction costs. As a framework for the adoption of BIM, the affected teams must have, within them, elements with BIM training and compatible work methodologies, one of them being the experience of working in a 3D philosophy, with software that allow the export of standardized files of IFC. In view of the above, is indicated the information considered essential to be included in the BEP [9].

The Project Information translates the basic project information, namely the identification of the owner of the work, the name and location of the project, the project delivery contracts, and the project description, unit systems and deadlines [9]. This information is mentioned in the contracts and forms part of the information made available in the tender or invitation process file. As information issued / available by the Owner of Work, which explains the requirements / obligations of a given tender, we can refer to the objectives of the Project, the general lines of design, the Functional Programs, the technical and budgetary constraints, the deadlines, the formats of delivery, etc. Another important issue will be the temporal allocation of all teams by specialty and by project phase, translated into a schedule of activities, preferably carried out in software compatible with this technology, including in these tasks the creation of virtual models (3D) and the consequent export, usually in IFC standard format. It will also be necessary to provide information on the costs of carrying out the project by specialty / phase and several authors refer to the inclusion of costs (hours estimate) with the BEP that should be distributed by each project phase.

Project Members identify all project stakeholders, as well as their contacts, and the teams to be considered. Considering the numerous specialties and the possible complexity of the project, the teams can be very extensive, if it is necessary to identify the technical teams for each specialty, its technical coordinator and the BIM Manager of each team [9].

The Project Objectives describe the objectives foreseen in the project and defined by the client. Having as the final objective of the project, and being an Architecture and Engineering project, the general objectives of the BIM implementation in project management can be proposed as: i) increasing the quality of the project (O1); ii) improve collaboration between specialties (O2); iii) reduction of project errors (O3); and iv) define the project's workflow (O4). To achieve these final goals, it will be necessary to define the purpose of the project regarding BIM, to improve the planning, project creation, construction, and operation of the enterprise (CIC, 2011). Once the objectives have been defined, the project team must analyse which BIM uses are best suited to achieve them. Thus, it is important to assign different priority levels to each mentioned objective (High, Medium, or Low). Reference is also made to the possible Uses by proposed objective: i) Programming, Space Analysis, Project Execution (O1); ii) Phase Planning, Project Execution and 3D Coordination (O2); iii) Existing Modelling Conditions, Design Review, 3D Coordination and Phase Planning (O3); and iv) Phase planning (O4).

The BIM Uses contemplate the definition of BIM uses necessary for the delivery of the BIM project to fulfil the requirements defined by the client [9]. Defining the potential value of BIM in the project and for its constituent members is one of the most important steps in the project planning process, allowing you to establish the overall goals for BIM implementation. Thus, in the BEP, the appropriate BIM uses must be identified considering the project's objectives [1]. For the determination of BIM uses, the twenty-five BIM uses identified in the CIC [1] were used as a basis, those referring to the planning and design phases being selected for this article, not considering those referring to the construction and operation of the building. In the planning phase, the selected BIM uses are "Programming", which corresponds to the evaluation of the efficiency and accuracy of the project's performance in relation to spatial requirements, and "Space Analysis", which represents the collection and evaluation of the information necessary for determine the ideal location for the project. Regarding the design phase, the BIM uses identified according to the BIM objectives were “Project execution”, “Design review”, “3D coordination”, “Phase planning” and “Existing modelling conditions”. The use “Project execution” refers to the creation of the virtual model, based on information from the construction elements. The “Project Review” corresponds to the process of analysis and validation of the model by the project stakeholders and those responsible for the quality assurance of the project. The use “3D Coordination” corresponds to the objective of reducing errors and incompatibilities in the model before the construction phase, through clash detection software during the project coordination process. BIM usage “Existing modelling conditions” refers to creating the virtual model according to the existing conditions. In the case of the study analysed in this document, the existing modelling conditions correspond to the CAD plans previously provided. The use “Phase planning (4D Modelling)” translates the process in which a 4D model is used to effectively plan the project phases or to determine the constructive sequence and the spatial requirements on site.

In the Project Responsibilities, the roles and responsibilities of all project stakeholders are assigned, according to the BIM uses assigned in each phase of the project [9]. Each BEP must include the existing BIM positions in the project as well as their responsibilities. For each BIM use, organizations and the respective number of members must be associated, helping each participant in the project to be aware of their responsibilities. It is also necessary to indicate the maximum responsible for the implementation of each BIM usage [1]. The person responsible for the implementation of each BIM use is the BIM Manager as he is the member responsible for the integration and control of the BIM methodology in all phases of the project life cycle [19].

BIM Design comprises the creation of an overview that determines the interconnections of information requirements with BIM uses. The process maps created are assumed as the basis of the BEP due to the creation of the graphic information flow of the project phases [9]. BIM Design describes the execution procedures of BIM projects, through process maps [1]. BIM process maps are diagrams that describe how to apply BIM in a project. According to the Business Process Model and Notation (BPMN) standard adopted by the BIM Project Execution Planning Guide, the implementation of process maps should be divided into two levels [1, 20]: i) Level 1 – General BIM Map: Relation between the BIM uses of the project under study and the exchange of information that takes place throughout the project's life cycle; and ii) Level 2 – Detailed map of BIM usage processes: Description of the processes of each BIM usage to define the sequence between the various processes to be executed. Reference of those responsible for each process, the content of the information and the sharing of information between processes. Creating the General BIM Map starts by adding each of the BIM uses defined as process maps. Then, the processes must be ordered chronologically, identifying the project phase corresponding to the process, as well as the parties responsible for defining the information necessary to implement the process and the information developed by the process. Finally, the BIM General Map must encompass the exchange and exchange of information regarding each process or between processes and responsible parties [1]. The development of process maps for BIM execution is carried out from the graphical representation defined in the BPMN standard [20].

Project stakeholders must define the collaboration procedures to be followed during project execution in order to ensure the correct sharing of information defined in the process maps [9]. The successful exchange of information in the project is dependent on the capacity for collaboration between all stakeholders. Thus, procedures for meetings about the project must be defined, by identifying the theme of the meetings to be held, the phase of the project to which they correspond, the frequency with which they are held, the participants and the place where they happen [1]. The themes defined for the case study are the review of the models created for each specialty, corresponding to the project design phase.

Quality Control corresponds to the determination of the general model for quality control of the BIM models created in the collaborative process. Among the most used control measures are visual checks and conflict detection (Moreira, 2018). To ensure the quality of all project templates, project teams must establish an overall strategy for this purpose. Each BIM element created throughout the project must be planned, considering the level of detail, file format and possible updates. All teams working for the BIM model must have a member responsible for coordinating the BIM work they perform [1]. Before the delivery of BIM models, the teams responsible for their elaboration, as well as all the members that are part of it, must carry out quality control checks on the project. For this purpose, all the checks carried out must be documented. Each team involved in the project must designate a responsible member, with the task of ensuring the execution of the quality control processes [1]. According to CIC (2011), the following checks must be carried out to be included in the quality control plan: i) Visual verification (Ensure that there are no unforeseen components in the model and that the project objectives were achieved, using a software navigation); ii) Interference verification (Detect problems in the model created from incompatibilities between specialties through a clash detection software); iii) Standards Verification (Ensure that the model meets all standards defined by the project team); and iv) Validation of elements (Confirm that the models created do not have unforeseen or ill-defined elements). In each of the checks, the organizations, or members responsible for carrying out the checks must be indicated, the software used and the frequency with which they are carried out [1].

The Technological Infrastructures comprise the indication of software requirements, hardware, technological licenses, platforms for the exchange of information and technical issues to be defined by those involved in the project [9]. To support BIM's collaborative work, it is essential that project teams have interactive virtual platforms that ensure the sharing of information and the existence of a common database for all project stakeholders [2]. Thus, each team responsible for the project must define the hardware and software requirements, the information sharing platforms and the necessary licenses, to ensure compatibility between all project models [1]. Regarding the software, it must be defined which ones are necessary, as well as the respective version, to execute each foreseen BIM use. File formats for transferring project information must also be established. As an example, it refers to some of the most used software, working in a 3D philosophy and allowing sharing between specialties (they will have to be compatible with IFC format): ArchiCad and Revit Architecure (Architecture); Revit Structure and TEKLA Structures (Structures); and ArchiCad MEP and Revit MEP (Specialties). The final delivery will have to encompass the entire BIM project at IFC standards. Regarding technological infrastructure for information sharing, BEP must include databases and communication and information sharing platforms for each BIM use, ensuring that all project stakeholders are aware of the storage and sharing locations. information. It also refers to technological platforms, considering the Integration of the Project in all its phases of the life cycle: SOLIBRI – BIM Coordination and BIM 360 (Autodesk platform).

The Model Structure includes the definition of the project information management methodology during the collaborative process between project stakeholders, namely the management of information exchange platforms [9]. After defining the collaboration procedures and the technological infrastructures necessary to carry out the project, BEP must consider the methods for creating, organizing, and controlling the project and the respective information sharing platforms. To this end, the CIC [1] defines the following topics: i) nomenclature of information files; ii) description of the organization of the project's information models; and iii) description of measurement systems. The organization of the models must be carried out from a disposition from the most comprehensive to the most detailed. The adopted methodology distributes the models by specialties, floors, and divisions.

Project Delivery consists of defining the project delivery strategy in each phase, as well as the format of the information to be presented [9]. The implementation of BIM must consider the project delivery methodology. In each delivery, it integrates the created BIM models, which are digital representations of the physical and functional characteristics of the elements designed to be used in the project [3]. The deliveries made must meet all the requirements demanded by the project owner and ensure that all objectives are met, as well as ensuring the quality of the information created [1]. The BEP must thus characterize the project model to be created, the phase to which it corresponds, the delivery date and the file format in which the models are submitted [1]. In the case of study, it is considered that the submitted models correspond to the projects of each specialty. All models are developed in the design phase and the proposed delivery dates correspond to the expected completion dates for the creation of each model. The file formats are in rvt, considering that all models were developed from the Revit software, except for the ArchiCad Architecture (Pln and Pla files) [21].

6. FINAL REMARKS

The adoption of BIM methodologies, associated with the centralization of information from the various specialties in a single model, presupposes a paradigm shift in the traditional industry. The evolution to industry 4.0 implies changes both in production systems and in business models. The implementation of the BIM methodology in Portugal in the field of Architecture, Engineering and Construction will be a reality in the short / medium term by Government entities, considering the recognition and gains from experiences well achieved in other countries of the world, however, for its correct adoption, there is still a need for regulation so that its dissemination becomes a national reality. At the level of project companies, internal strategies can be developed to implement this methodology, such as training employees and creating a nucleus responsible for developing the company's BIM skills. This nucleus should be responsible for creating and maintaining the BIM collaborative models, as well as for monitoring the projects itself. It must be informed about the subject, through the follow-up of groups oriented to the evolution of this concept. This group will also be responsible for creating the BIM Execution Plans for each project with BIM bases, a document that systematizes the project objectives, protocols for using tools and collaborative processes among its participants.

In recent years, some project offices have been implementing strategies to approach BIM methodologies. The BIM implementation in each organization depends on the activities developed to prepare the organization for this implementation, such as developing the documentation for delivery in BIM format and adapting the work processes involved. These implementation strategies often involve the creation of a nucleus responsible for innovation at the level of the AECO sector. Design offices can implement the BIM methodology gradually, exploring BIM tools in projects of different scales, and in various specialties, even the less conventional ones, such as geology and geotechnics, and in multiple project phases. Another strategy for implementing this methodology is the training of its employees, both engineers / architects and designers, to “transform” them into BIM auditors and modelers, respectively. These training actions can be promoted either by the innovation nucleus of the companies or by external entities. The nucleus created with the objective of developing the company's BIM competences should create BIM bases, through the creation of support documents for the development of the BIM project, creation of project models, creation of element libraries for the realization of BIM projects, and respective maintenance. For projects where BIM is implemented, a BIM Manager must be designated. This entity will be responsible for the internal and / or external BIM coordination of the project and will have as its main function its monitoring, through the preparation of the BEP, the creation of specific objects needed during the modelling, definition, and guidance of modelling strategies and through the support to different modelers. The BIM Manager must also audit BIM models, methodologies, and processes, as well as being responsible for creating software that streamlines daily production.

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References

[1] CIC (2011). BIM Project Execution Planning Guide -Version 2.1. buildingSMART alliance, pp. 1–135. doi: 10.1017/CBO9781107415324.004.

[2] AEC-UK (2012). AEC (UK) BIM Protocol Project BIM Execution Plan.

[3] BCA (2013). BIM Essential Guide For BIM Execution Plan’. Singapore: Building and Construction Authority. Available at: www.bca.gov.sg.

[4] MIT (2016). MIT Design Standards -BIM Execution Plan v6.0.

[5] USF (2018). BIM Project Execution Plan Template - For Architects, Engineers and Contractors. University of South Florida.

[6] Hunt, C. (2013). The Benefits of Using Building Information Modelling in Structural Engineering.

[7] Ganah, A., Jonh, G. (2017). BIM and project planning integration for on-site safety induction. Journal of Engineering, Design and Technology, 15(3), pp. 341–354. doi: 10.1108/02656710210415703.

[8] McGraw Hill (2014) The Business Value of BIM for Construction in Major Global Markets.

[9] Moreira, P. (2018). Integração do BIM na Gestão de Projetos de Edifícios. Dissertação de Mestrado. Universidade de Aveiro.

[10] Eastman, C. et al. (2011) BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors. 2nd edition.

[11] Smith, P. (2014). BIM implementation -Global strategies., Procedia Engineering, 85, pp. 482–492. doi: 10.1016/j.proeng.2014.10.575.

[12] Geroski, P. (2000). Models of Technology Diffusion. Research Policy, 29, 603-625.

[13] Carvalho, P. (2016). Análise estatística do estado de implementação da tecnologia BIM no setor da construção em Portugal. Dissertação de Mestrado. FEUP.

[14] Succar, B. and Kassem, M. (2015). Automation in Construction Macro-BIM adoption: Conceptual structures', Automation in Construction. Elsevier B.V., 57, pp. 64–79. doi: 10.1016/j.autcon.2015.04.018.

[15] Arayici, Y., Kiviniemi, A., Kiviniemi, A., Coates, S., Koskela, L., Kagioglou, M., Usher, C., O'Reilly, K. (2011). BIM implementation and adoption process for an architectural practice. Project BIM implementation.

[16] Lino, J., Azenha, M., Lourenço, P. (2012). Integração da Metodologia BIM na Engenharia de Estruturas, Encontro Nacional Betão Estrutural -BE2012, pp. 24–26.

[17] Silva, J. (2013) Princípios para o Desenvolvimento de Projeto com Recurso a Ferramentas BIM. Dissertação de Mestrado, FEUP.

[18] Simões, D. G. (2013). Manutenção de edifícios apoiada no modelo BIM. Dissertação de Mestrado. Instituto Superior Técnico.

[19] Costa, A. et al. (2017). Guia de Contratação BIM'. Instituto Superior Técnico.

[20] BPMN (2011) Business Process Model and Notation (BPMN). 2.0. Available at: http://www.omg.org/spec/BPMN/2.0.

[21] Antunes, B. (2015). BIM Execution Plan Proposal Synergies with PMBOK Civil Engineering. Dissertação de Mestrado. Instituto Superior Técnico.