BIM Maturity Model for the Nacional Industry

Evaluation, Planning and Action

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EXTENDED ABSTRACT

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Abstract

The Building Information Modeling (BIM) is considered, in the environment of architecture Engineering and Construction industry (AEC), as the new paradigm that will shape the sector in Portugal, develops it and modify it in a radical way. BIM proposes a working method that, according to academic literature and professional studies of the area, dramatically increases the productivity of the industry agents, while minimizing the costs associated with the undertaken activities. It presents itself as an opportunity for sustained sector growth, encouraging transparency, integration, cooperation and optimization.

Although the overall analysis of BIM maturity at national level has already been carried out by other authors, along with an early normalization of the sector according to the BIM concept, the need to establish tangible objectives to assist the process of implementing BIM by entities and organizations have not been satisfied. Even if the layout of the following steps already exists and is used in various countries, there is no direct relationship and no compatibility with the real needs of the AEC industry in Portugal.

Thus, in order to counter the problems mentioned, the present work identify different aspects and valences on which BIM is developed, defining what are called categories, with each subdivided into five levels of maturity well characterized. Based on the resulting list of categories, and for each input of it, an Impact vs. Effort analysis was performed resorting the data collected through a Focus Group.

With this analysis it was possible to determine different stages associated with the collected data, defining a strategy to be followed when implementing BIM.

It is expected that the result of this work is seen, by the industry involved, as the basis for the development of a useful and essential tool in BIM implementation process, but also as a way to determine state of BIM maturity of an organization or even of the national industry.

KEYWORDS: Building Information Modeling, Information, Implementation, Maturity, AEC Industry, Stages, Model

1 Introduction

BIM implementation emerges as a complex process that must be addressed in a structured and systematic way. The need by the implementing entity of BIM, "...to map processes, identify information exchange, adapt their organizational structures and implement methodologies and integrated BIM implementation plans..." [10], encourages various working groups dedicated to the operation of BIM capabilities to develop methods, maps, guides and guidelines as a first step to a possible implementation at national level, as well as the construction of foundations for the beginning of the regulatory process and normalization of the industry according to the BIM paradigm.

The presented research study aims to develop a **BIM ACTION BASED MATURITY MODEL**. To this end, it is essential that this model is focused on evaluating all the needs that a BIM implementation is subject, but also ensures an easy visual analysis, making the model a useful and essential tool to be used by an implementing entity of BIM. Thus, with the overall objective of the development of this model, the main goals of this work are:

1. Analysis of the current state of the AEC industry at national level, making the parallel with the present state of the industry in
countries with a more advanced BIM implementation and use;

2. Defining a list of needs considered as essential in the BIM implementation process and representative of all aspects on which BIM is developed within an organization;

3. Preparation of a maturity model that evaluate and locate the state of maturity, based on the previously defined list of needs. A model which functions as an auxiliary tool in the BIM implementation process, explicitly identifying different stages and targets to be taken into account by the implementing entities, as well as plans of action to follow.

2 State of the Art
2.1 BIM Concept

The BIM concept comes under the scope of the AEC essentially as an alternative way of modeling over traditional methods used since the beginning of computerization, such as the use of CAD tools as base of different designs of various specialties. According to the National Institute of Building Sciences (NIBS), "... current BIM examples tend to be virtual models of individual or small clusters of buildings executed in proprietary software for the purpose of supporting the design..." [1].

Although many of the BIM uses only complement traditional methods of conducting projects, this concept has as main objective the coordination of different specialties instantly, quickly, concisely and in a rigorous manner, in order to reduce, or even eliminate, any incompatibility errors between designs, thereby reducing costs associated with unforeseen changes, resulting in exponential efficiency in the execution of the work and further exploration of real state.

The potential of the BIM concept, as well as its capacity to integrate different players in the sector, will certainly be dependent on the adoption of standardized processes alongside the acquisition of technological equipment able to handle the necessary software, plus training and education needed to handle and analyse correctly the information provided. Consequently, arises the BIM paradigm defined by the triad of policies, processes and technology.

![Figure 1. BIM paradigm layout](image)

The definition of all entities involved in the BIM concept is essential to understand the dynamics and information flows that follows adoption of BIM methodologies. Exchanges of information and knowledge are characterised by being of type push-pull. This term transmits on one hand the idea that information sharing is encouraged by one of the players through a specific need, and subsequently developed by the other player (push) and, on the other hand, the idea that sharing is initiated by development of information, which would create a need (pull). In short, table 1 identifies all entities associated with each vector of the BIM paradigm, giving an idea of how relations works between each other. Moreover, what are the major challenges in BIM implementation between Products and Relations that can be linked to BIM Maturity Levels.

2.2 BIM Maturity Levels

The definition of BIM maturity levels in the adoption process of adjacent methodologies to this new concept for the AEC industry is essential for a proper BIM implementation in any organization.
Once identified all possible involved players, so that a BIM system ensures a successful exchange of information (i.e. minimizing loss of information) and an exponential interoperability, it is necessary that those who are interested in implementing BIM methodologies, do so with a clear sense of their starting position and a clear planning of subsequent follow-up activities. In this planning and with the goal of BIM implementation, Succar [2] consider an introductory level and three subsequent levels of maturity:

- **Level 0: Pre-BIM**
- **Level 1: Modeling**
- **Level 2: Collaboration**
- **Level 3: Integration**

### Level 0: Pre-BIM

The introductory BIM level of maturity can be characterized by the 2D representation of information. At this stage, all the information is independent and requires association and interpretation to be performed by different stakeholders. The collaboration between different parts occurs in a linear way, which results in a time consuming and financial expensive exchange of information [2].

### Table 1. Entities, Products and Relations between entities in the BIM paradigm (adapted from [4])

<table>
<thead>
<tr>
<th>Policies</th>
<th>Processes</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Organization of the work activities over time and space</td>
<td>All software, hardware and collaborative platforms, as well as all construction related technological equipment</td>
</tr>
<tr>
<td>Entities</td>
<td>Governments, educational institutions, laboratories, insurance companies and regulatory institutions</td>
<td>Project owners, builders, contractors, architects, engineers, statisticians, researchers</td>
</tr>
<tr>
<td>Products</td>
<td>Guides, regulations, standards, contracts and educational programs</td>
<td>Construction products and related services</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relations</th>
<th>Push in the other vectors</th>
<th>Pull in the other vectors</th>
<th>Push - Pull within the same vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policies</td>
<td>Specialized staff</td>
<td>Interoperability from technology</td>
<td>Knowledge exchange between trainers and researchers</td>
</tr>
<tr>
<td>Processes</td>
<td>Introduction of concepts</td>
<td>Experiences and knowledge from Processes</td>
<td>Instructions and clarification requests between professionals in the same field</td>
</tr>
<tr>
<td>Technology</td>
<td>Case studies to Policies</td>
<td>Development of solutions from Technology</td>
<td>New equipment and innovative solutions for Policies and Processes</td>
</tr>
<tr>
<td>Technology</td>
<td>Feedback to Technology</td>
<td>Standards, guidelines and regulations from Policies</td>
<td>Requests from Processes</td>
</tr>
<tr>
<td>Technology</td>
<td>Standards, guidelines and regulations from Policies</td>
<td>Requests from Processes</td>
<td>Hardware capacity and software requirements</td>
</tr>
</tbody>
</table>

### Level 1: Modeling

Modelling itself initiates the BIM methodology. In this stage there is an effort by each design discipline to create a base model of 3D representation with parametric information associated. However, the exchange of information continues unidirectional and communication remains unsynchronized and dissociated [2].

### Level 2: Collaboration

Following the definition of level 1, the collaboration of information factor comes inherent to 3D modeling. Mean by collaboration the ability, of different specialties associated to the same project, to share information and work on the same model at the same or at different stages of the project’s lifecycle [2].

### Level 3: Integration

At this level of maturity, the system should be based on an information network working in all directions, linked and constantly updated. The interventions made by different entities cause an instant effect on the common model of the project. This network integration allows fluid, associated, common and updated communication, ensuring project uniformity in all its aspects. It is, at this level, also
available an infinite ways of information analysis, regarding many dimensions of the project, linking data from all entities and all stages of the life cycle [2].

2.3 BIM Implementation: The U.K. Situation

The implementation policy adopted by the United Kingdom on the BIM issue is of great interest as an object of analysis and reference. This is due to the fact that the BIM adoption in U.K. have been considered mandatory in the short term for public projects. Consequently, there was planned a methodology of implementation that should be followed by all industry entities [8]. According to the BSI B / 555 Committee [5], it was developed a legislative guide that allows the British industry not only to have a reference to the better management of built assets, but also supports the Committee’s mission to reduce total life cycle costs, associated risks, carbon emissions and average time of completion of engineering, architecture and construction projects.

From the implementation process occurred in the United Kingdom stand out two main standardizations:

- **PAS1192-2 Specification for information management using BIM** [6];
- **AEC (UK) BIM protocol** [7].

Based on these and other standards, and in order to simplify the description of technologies and ways of working at the BIM implementation methodology, it was defined the concept of maturity levels.

For better understanding of the maturity diagram presented in figure 2, follows a brief definition for each of the maturity levels:

0. Use of paper or 2D CAD design formats as information exchange mechanism;

1. Use of 2D / 3D CAD based on the standard BS 1192: 2007 indications, resorting collaboration tools that generate environments of common information exchange. At this level it should already be considered standard data structures and formats. However, different designs are administered alone and without integration;

2. 3D BIM model management tools, in which elements are provided with attached information and properties. At this level there is already integration between different projects, however this integration is still dependent on entities performance. As a result, appears the term "pBIM", i.e. integration based on the owner's dependency (property). The model must present a 4D (time) and 5D (cost) analysis associated with the BIM tool made model;

3. Full integration of information and processes by all stakeholders, using IFC formats. Collaborative model function, constantly updated and accessible. This is where the term "iBIM" appears, referring to the full interoperability of all information systems.

As can be seen, there is a strong proximity between PAS1192-2 [6] maturity levels and the ones defined by Succar [2]. One of the main motivations that led to the continuation of this research study was the realization that this maturity levels hardly could be adopt by the national scene, to an industry in with so little experience in BIM.
3 Maturity Model

3.1 Methodology

The definition of a work methodology arises, in the context of the current Portuguese industry situation, as a crucial first step for a successful BIM adoption. This is due to the lack of standardization regarding BIM implementation which makes the defined maturity levels, as those presented in the previous chapter (United Kingdom), proves to be vague and hardly adaptable to the reality of the national industry.

Moreover, this work appears in the context of CT197-BIM (Technical Committee for BIM Standardization), which is subdivided into four sub-committees. In order to work effectively together, all sub-committees must have a well-defined working methodology and activity sequences.

Thus, firstly it was defined a working method which corresponds to a first approach to BIM implementation, which will result in a first list of industry needs.

Then it was performed a discussion in a Focus Group in order to correct/complete the referred list of needs and also identify other faults related to BIM in the industry. In addition, the members of the Focus Group responded to an inquiry with the aim of collecting data on the same list.

Finally, it was performed an analysis of the collected data in order to present a plausible maturity model, in which maturity stages will be defined, covering all needs identified in the previous steps.

In order to diagrammatize the continuous work process to be done by the members of the technical committee CT 197, namely the members of the Subcommittee 1 (SC1), the figure 3 presents a diagram with the working methodology to be adopted.

3.2 Vision

The analysis of the current state of the industry and its economic framework, as well as studies and learnings based on success BIM implementation cases in Portugal are some of the starting points for developing an appropriate BIM maturity model, but does not obviate the definition of what might be called as vision/mission, a reference of understanding for those who will use the model.

The main objective is to develop the construction sector in an integrated and technologically advanced way, a development led by companies with progressive thinking, constituted by increasingly specialized and competent elements. It is with the compliance of these guidelines that industry will reach greater productivity levels, optimized ways of working, high and successively increasing sustainability standards, and level of competitiveness that puts the national construction sector abreast of the best in international scope.

Thus, alongside a precise and accurate standardization, it will be logic to develop a model.

![Figure 3. Work methodology to be adopted by CT 197 SC1](image)
that allows the assessment of BIM maturity, both at sector and organizational level, providing help in setting priorities in the implementation process and progression of the adopted BIM concept.

### 3.3 Needs Definition

The first approach in the definition of needs has been developed according to this study, trying to cover all possible angles and perspectives of BIM. To achieve this, Capability Maturity Model Version 2.0. [9] was used as a support document. The detail and development of each area of needs, designated as CATEGORIES, has been adapted according to the opinion and advice of the members from the Focus Group. Below presents the final list of CATEGORIES, alongside a small phrase that defines each one:

- **A - Information – Data Richness**
  - FROM DATA TO METADATA THAT GENERATES INFORMATION

- **B – Life Cycle Scope**
  - PROGRAM, PROJECT, CONTRACT, CONSTRUCTION, OPERATION, MAINTENANCE AND REUSE

- **C – Roles or Disciplines**
  - SPECIALTIES AND ACTIVITIES

- **D – Model of Management**
  - INTEGRATION OF INFORMATION AND BUSINESS PROCESS

- **E - Synchronization**
  - ACTUALITY AND REPLY

- **F - Accessibility and Sharing**
  - DATA AVAILABILITY

- **G - Dimensions**
  - INTEGRATION AND ANALYSIS CAPABILITIES

- **H - External Information**
  - BOUNDARIES AND SCOPE OF THE MODEL

- **I - Infrastructure**
  - HARDWARE, SOFTWARE AND NETWORK

- **J - Information Format**
  - FROM ISOLATION OF INFORMATION TO ITS FULL COMPATIBILITY

- **K - Education**
  - INTEGRATION OF KNOWLEDGE AND EXPERIENCE IN THE ORGANIZATION

Each category represents different valences in which BIM implementation is based. The relationship, terminology and hierarchy between the different levels of each category meet the reasoning outlined in Figure 4.

### 3.4 Data Collection

In order to allow a more tactile and graphical analysis, it was created a matrix that relates the impact of adopting a certain level of the categories listed with the effort involved in the same adoption by the entity / organization.

![Figure 4. Outlining terminology and hierarchy of categories and corresponding maturity levels](image)

To this end, an inquiry was carried out which aimed to the simultaneous determination of the impact and the effort of reaching a certain level (1,2,3,4 and 5) from the immediately preceding level (none, 1, 2, 3 and 4) for each and all categories (A, B, C, ..., J and K).

It was intended that the impact and effort values were rated on a scale of 1 to 10, where 1 represents the lowest effort or impact and 10 the greatest effort or impact to be involved in reach and full operate the respective maturity level regarding a BIM use.

Once obtained the inquiry results, it is important to note that, due to the current BIM development status in the industry, only will be relevant in BIM adoption values that represent a considerable impact level. Having this in mind, it shall be
considered as acceptable zone the whole area corresponding to medium and high impact, which is designated as priority zone, in which it shall be highlighted the medium and low effort zone, which is designated as highlighted priority zone.

In order to match the scale of 0 to 10 used in the conducted inquiry with the proposed matrix, which enabled a more accurate processing of data, it proceeded to a subdivision of the matrix area.

### 3.5 Data Processing

To be able to analyse the collected data, it was necessary to develop a method that produces a more objective interpretation, and hence it could determine the actual relevance of each level corresponding to each category.

Thus, it was developed a new matrix, called Relevance matrix, based on the definition of the Impact vs. Effort matrix, but with the association of a numerical score, depending on the zone where the average value of responses regarding a certain level would be.

In relation to the adopted classification system, it is important to note that, as can be seen in the Relevance matrix, the score is attributed in reverse. This means that the most relevant zone is ranked lower and the least relevant zone is ranked higher. The adoption of this method is justified by the fact that, subsequently, it will be built a relevance graphical representation of all levels, together with all categories, thus facilitating the interpretation of results and definition of maturity stages associated with each level's relevance.

By assigning a score to the average values of the responses from each level of the different categories (relevance matrix), and considering the assumption that no subsequent level can be implemented without the full adoption of the immediately previous level, it was prepared a chart column representing the accumulated values\(^1\) from the scores assigned, fulfilling the hierarchy of levels within each category. This cumulative score can be referred as maturity scale, existing one for each category.

### 3.6 Development of the Maturity Model

The concept of maturity stage arises as a need to create objective goals in the process of BIM implementing methodology. Similarly to what is stipulated in PAS1192-2 - Specification for information management using BIM [6], which defines maturity levels reachable by entities wishing to adopt BIM methodology, the attaining of a certain

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1. Fictitious values, i.e. not corresponding to the amounts collected by the responses in the inquiry. These values are used and referred to whenever it is necessary to use concrete examples to better understand the methods and reasoning used both in the preparation of matrices and in the analysis of these results.
STAGE provides accurate identification of the "location" of the entity/organization with regard to BIM maturity and implementation process.

The existing interconnection and unavoiiable relationship between the different categories implies that the reach of a certain maturity STAGE is dependent on the implementation of all matching levels (i.e. all level 1 implemented mean achieving the maturity STAGE 1), and at the same time forcing the implementation of all minors levels contained in this STAGE. The levels (one or more) which determine transitions between maturity STAGE are designated as hinge levels.

Using the figure 9 to illustrate the correct method of use and interpretation of the maturity STAGE concept represented in the maturity scale, the following points clarifies the same use:

- The entity that intend to achieve STAGE 1 should ensure full functionality of the levels A1 and B1, and may or may not have started the implementation of level A2;
- If the entity does not fully implement both A1 and B1 levels, it has not reached the STAGE 1, regardless of the remaining implemented levels. For example, if category B is fully adopted (up to level B5) but the entity has not implemented A1 level, it does not reach STAGE 1;
- For the entity to reach STAGE 2, it has necessarily to have implemented levels A1, A2, A3, B1 and B2, but it may or may not have started the implementation process of level A4;

Basically, for a particular maturity STAGE to be reached, it is necessary to fully implement all levels that are below the STAGE delimiting line, being that it fails if any of these levels is not fully implemented, regardless of the remaining levels. The full adoption of the BIM methodology to be taken by the entity/organization will correspond to the achievement of the last maturity STAGE (STAGE 5), while implementation process must go through all established STAGES.

3.7 Final Product

After the precise definition and validation of maturity STAGES, is presented in Figure 10 the final form of the developed maturity model, which features all of the eleven categories, each one containing five maturity levels. It also identifies the division

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2 A minor level represents greater relevance due to the reverse classification adopted in the relevance matrix. This fact is justified by the graphical possibility of each stage covers the largest number of relevant levels, that is, levels below the hinge level(s).
between BASE STAGES and FINAL STAGES, respectively corresponding to the STAGES covering more levels and the ones covering fewer.

4 Results and Discussion

With the presented model, and its maturity STAGES well defined and delimited, it is finally possible to draw the following conclusions about the results:

The category presented as the one with the best Impact vs. Effort relation (biggest relevance) is category D – Model of Management.

In contrast, the categories that are less valuable in terms of Impact vs. Effort relation (lower relevance) are categories B - Life Cycle Scope and H - External Information.

STAGE 1 defined in the maturity model is characterized by an even development of all the firsts levels, while only in STAGE 2 arises a disturbance in that uniformity. STAGE 3 sets up the adoption of levels 4 and 5 of the other categories, with the exception of a few top levels of the two categories of less relevance: Level 5 Category and levels 4 and 5 of category H. This STAGE already requires a high standard of BIM maturity, with nine of the eleven categories fully implemented. From the practical point of view, it is considered that an organization that reaches STAGE 3 is already an organization that operates in BIM. The remaining STAGES (4 and 5) function as terminal stages in the BIM implementation process.

5 Conclusions

To conclude, the maturity model developed and presented works as a support tool in the BIM implementation process.

The developed work, including the inquiry sample that was appealed in order to collect information, served to validate the model, established arguments for the definition of STAGES, forms of interpretation and analysis. The model as presented was approved by CT197 members in a recent workshop.

The necessity to divide the model into two types of STAGES (Base and Final STAGES) not only works as an organizing and clarifying method for those who make use of the model as a tool, but also as a suggestion for distinct moments of BIM implementation, considering an industry so undeveloped such as the Portuguese, regarding the BIM concept.

The development and improvement of the results presented in this work, particularly the enlargement of the inquiry sample, would value the final results, so that, in the future, it is possible to proceed to a national level of BIM implementation, comparable to the international implementation that have occurred to date.

Figure 10. Maturity Model
References


