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# ANALYSIS OF THE BIM APPLICATIONS FOR THE ARCHITECTURE, ENGINEERING AND CONSTRUCTION PROJECT MANAGEMENT: A BIBLIOMETRIC APPROACH

**Martínez-Rojas, María (1); Durán-Álvarez, Joaquín (2); Martínez-Aires, MD (3); López-Alonso, Mónica (4)**

(1) Universityof Granada (UGR), +34 958 246297, e-mail: mmrojas@ugr.es (2) UGR, e-mail: jdaeuat@ugr.es (3) UGR, e-mail: aires@ ugr.es (4) UGR, e-mail: mlopeza@ugr.es

## ABSTRACT

*Building Information Modeling (BIM) is a current methodology that provides a framework for collaboration in a multidisciplinary environment. It facilitates the integration of all the involved parties in the Architecture, Engineering and Construction (AEC) processes.Although this technology is not recent, the last years it has been conducted a greater diffusion of the opportunities that this methodology can bring in various management processes during the project lifecycle, such as; safety, sustainability, planning, energy efficiency, cost management, knowledge management and risk management.This article presents an analysis of the proposals that have been published in prestigious databases in order to identify the domain of application of BIM in the project management domain.*

***Keywords:*** *BIM, AEC, Project management, bibliometric analysis*

## RESUMEN

El modelado de información de construcción (BIM, BuildingInformationModeling) es una metodología de trabajo que proporciona un marco de colaboración, en un entorno multidisciplinar, que facilita la unión/integración de todas las partes involucradas en los procesos de la industria de Arquitectura, Ingeniería y construcción (AEC, Architecture, Engineering and Construction). Aunque esta tecnología no es reciente, ha sido en los últimos años cuando se ha producido una mayor difusión de las oportunidades que esta metodología de trabajo puede aportar en los distintos procesos de gestión durante el ciclo de vida del proyecto, tales como; seguridad, sostenibilidad, planificación, eficiencia energética, gestión de costes, gestión de conocimiento y gestión de riesgos. Este artículo presenta un análisis de las propuestas que han sido publicadas en bases de datos de reconocido prestigio con el fin de identificar el dominio de aplicación de esta tecnología dentro del ámbito de la gestión de proyectos.

**Palabras claves:** BIM, AEC, Gestión de proyectos, Análisisbibliométrico

## 1 INTRODUCTION

Building Information Modelling (BIM) is a flourishing technology and its approach is being used in the Architecture, Engineering and Construction (AEC) industry of different countries. BIM is a successor to the computer-aided drafting (CAD) which started in the 1980s and is intended to bring a clear advantage over CAD. It was initially based on two dimensional drawings and lately on 3D views. However, these drawings lacked the interactivity and the change in one view was not automatically reflected in other views (SACKS et al, 2004; KADARDEEN, 2010).

With the advent of BIM, since the beginning of the 21st century, it has been possible the automatic updating of views once the change is made in one view by the production of intelligent 3D/4D models. Besides the geometry information, BIM is also meant for modelling the functions and behaviour of building systems and components (SACKS et al, 2004). Schlueter and Thesseling(2009) defined three major types of information involved in BIM – geometric, semantic and topological. Geometric information means the 3D modelling of a building, and semantic information includes the properties of components. Topological information describes the dependency relationship between properties and components.

The main objectives of BIM in the AEC industry are; to enable the integration (HALFAWY & FROESE, 2007; WEIMING et al, 2009), easy sharing of information and convenient collaboration throughout the project life cycle (LI et al, 2014;HANNELE, 2012). In addition, it is essential to carry out the continuous changes during the design (LEE et al, 2015) and the execution phase that involves a constructive process and to update all the parameters and implicated agents (HALFAWY & FROESE, 2007; SHEN et al, 2010;KU& TAIEBAT, 2011). This is where BIM becomes essential.

In this paper, a bibliometric analysis is conducted in order to identify the areas of application of BIM in AEC project managementdomain,in addition to show how it has been become essential for its use in the project life cycle management.

## 2 METHODOLOGY

The bibliometric application that have been used, SciMAT (COBO *et al*., 2012), combines both performance analysis and scientific mapping tools to analyze a research field and to detect and visualize its conceptual subdomains (particular topics/themes or general thematic areas) and its thematic evolution. Additionally, three stages were defined to analyze the themes and thematic evolution of the research field.

### 2.1 Detection of research themes

The data sources used were the ISI Web of Science and Scopus. Database searches for "Building Information Modeling","BIM", "AEC" and "Project management" were performed. During the search process diverse constraints were established; subject areas or source title, in order to obtain the articles containing the keywords to be analyzed.

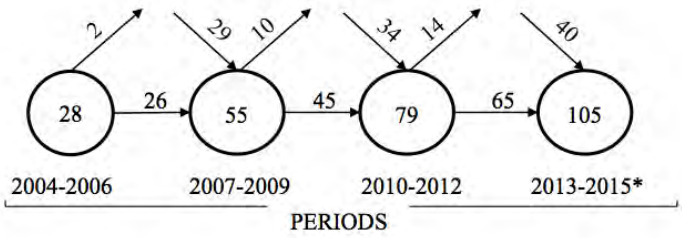
After the results were imported into SciMAT, a significant amount of effort was dedicated to cleaning up the data. First, duplicate documents and those which did not belong to the study area were eliminated. Second, the data was subject to preprocessing. This is perhaps one of the most crucial steps for improving the quality of the units of analysis (mainly words) and is key to obtaining better results from the scientific mapping analysis. In this process, the data was normalized by combining singular and plural forms, as well as grouping together different terms relating to the same concept. Misspelled words were also detected and combined with their corresponding representative. Once pre-processing was completed, 417 articles and 2750 keywords were available for analysis.

The analyzedperiod (2004-2015*) was divided in-to fourthree-year periods.Before 2014 there are few publications and it is in mid of the previous decade when BIM begins to gain importance in terms of the number of publications(AZHAR, et al., 2012). Figure 1

*In 2015, only publications published up to April are included.

shows the overlapping-items graph across the two consecutive periods. The circles represent the periods and their number of associated items (unit of analysis). The horizontal arrow represents the number of items shared by both periods. The diagonal incoming arrow îrepresents the number of new items in, for ex-ample, Period 2, and the diagonal outgoing arrowì represents the items that are presented in Period 1, but not in Period 2 (COBO, 2012).

**Figure 1. Overlappingitemsgraph**




SciMAT performs various processes to locate keyword networks that are strongly linked to each other and that correspond to centre of interest or to research problems that are the object of significant interest among researchers (COBO, 2012).

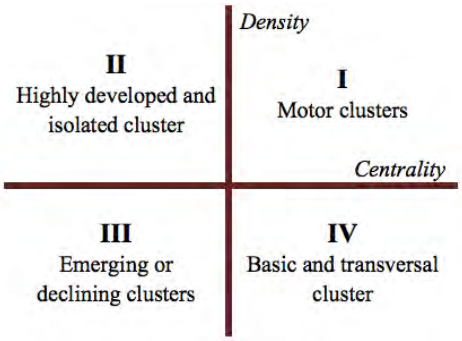
## 2.2 Buildingstrategicdiagrams

In the building strategic diagram, each keyword network or theme can be characterized by two parameters (CALLON et al.,1991):

- Centrality: Measures the strength of external ties to other themes. This value can be under-stood as a measure of the importance of a theme in the development of the entire re-search field analyzed.
- Density: Measures the strength of internal ties among all the keywords describing the re-search theme. This value can be understood as a measure of the theme's development.

Themes in the upper-right quadrant (I) (Fig. 2) are both well developed and important for the structuring of a research field. They are known as the drivers or principal themes of the specialty given that they exhibit strong centrality and high density.

**Figure 2 -Thestrategicdiagram**




Themes in the upper-left quadrant (II) have well-developed internal ties but unimportant external ties and so are of only marginal importance for the field. These themes are very specialized and peripheral in character. Those in the lower-left quadrant (III) are both weakly developed and marginal. They have low density and low centrality and mainly

represent either emerging or declining themes. The themes in the lower-right quadrant (IV) are important for a re-search field, but are not developed. Hence, this quadrant groups transversal and general or basic themes.

Once the knowledge base is ready, the scientific mapping analysis can begin. To build the maps, the tool has an eleven-step process that must be completed.The parameters to be analyzed are selected in this stage, such as period, unit of analysis, data reduction (the data are filtered using a minimum frequency threshold), network building, selection of the performance and bibliometricquality measures, etc. (COBO, 2011a, b).

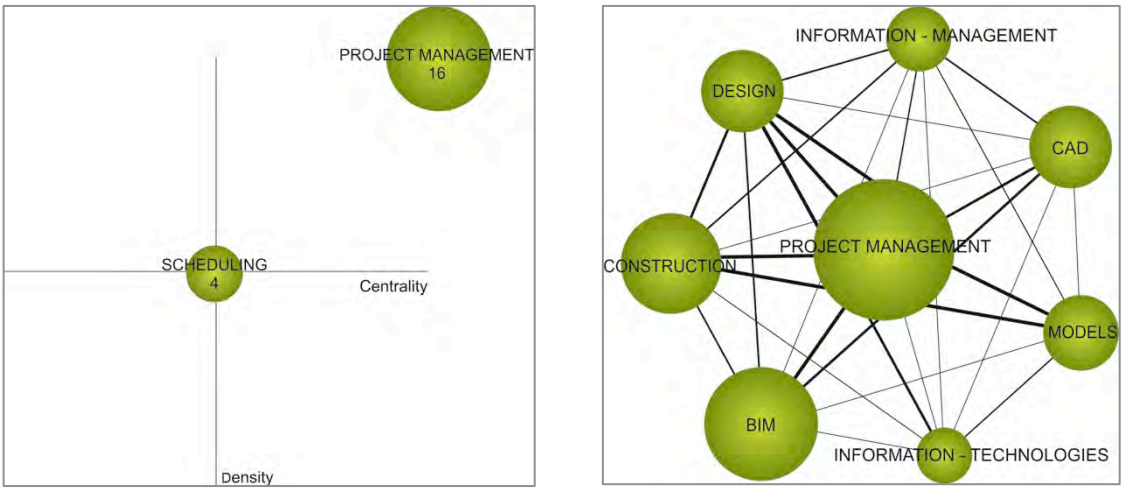
### 2.3 Conducting a performance analysis

In this phase the most prominent, productive, and highest impact subfields can be detected by measuring (quantitatively and qualitatively) the relative contribution of themes and thematic areas to the whole research field.

## 3 RESULTS AND DISCUSSION

In the 2004-2006 period can be observed that the number of publications are focused on the project management concept (Fig. 3 (a)). Also, the strategic diagram shows how the Scheduling term begins to have relevance in the analysed domain, although it is not defined if it will be a motor concept in the future. During the analysis of the results, it has been observed that in its thematic networks, the termscheduling is associated with the following concepts: cost and industry-foundation-classes (IFC).

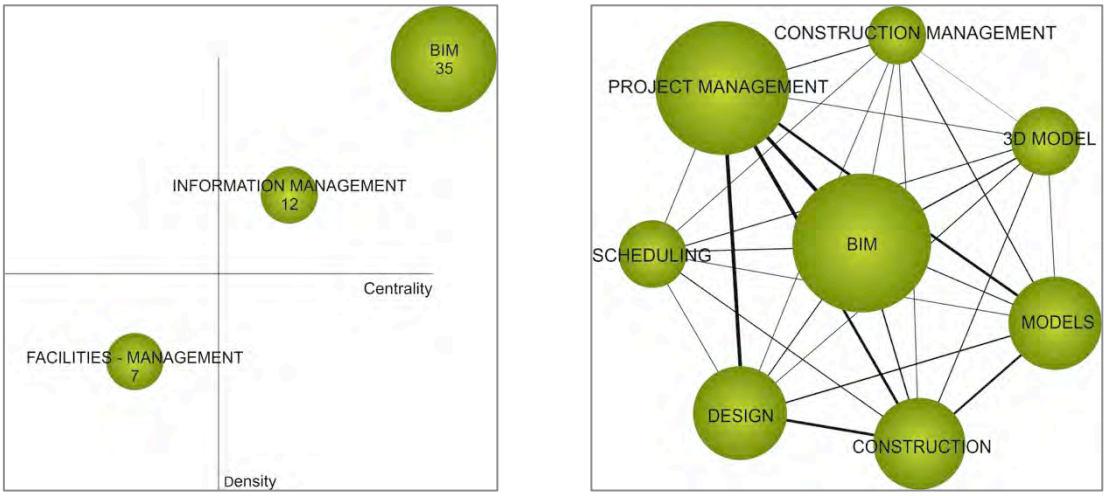
**Figure 3 – (a) Strategic diagram Subperiod 2004-2006 (b) Thematic networks related with PROJECT-MANAGEMENT**




(a) (b)

Fig. 3 (b) shows the thematic networks related toProject management.As can be observed, the most prominent relation is with BIM. Also, there is a relation with the information technologies concept. It is not surprising thatthey begin to be common in the project management domain because of the benefits that they provide. Also, project management is associated with an essential concept that is closely related to BIM: Information management concept.

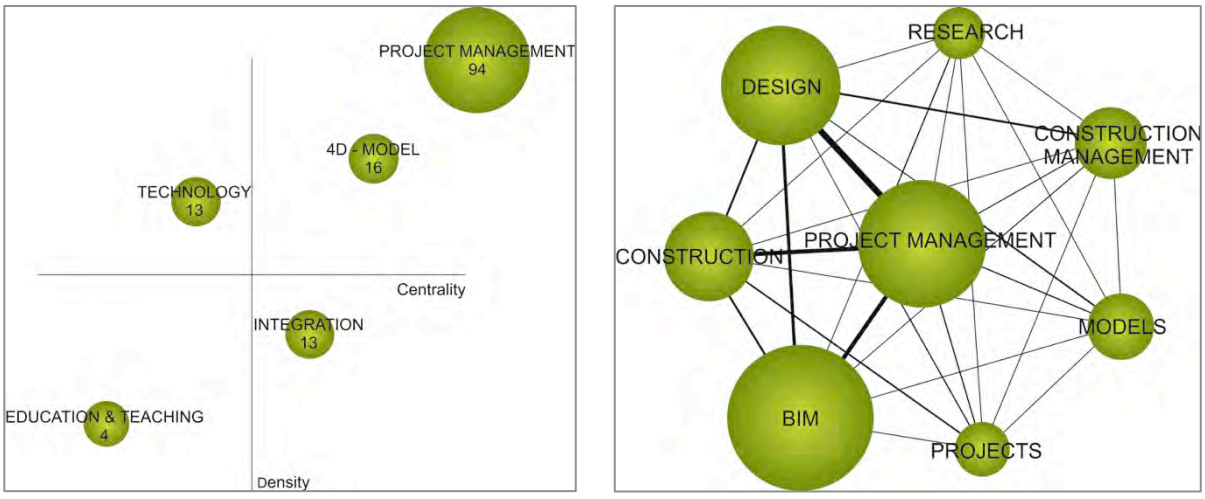
**Figure 4 – (a) Strategic diagram Subperiod 2007-2009 (b) Thematic networks related with BIM**




(a) (b)

In the 2007-2009 period the motor cluster is BIM (Fig. 4 (a)).This does not mean that previous concepts are not relevant hereinafter. The Information management concept is another motor cluster and in its thematic networks is linked with safety management, life cycle, cost and IFC. Finally, in this period, the benefits of BIM in the last phase of the project life cycle are investigated, since Facilities management concept appears as emerging cluster. In the thematic networks related with BIM (Fig. 4 (b)) can be observed a strong relation with the project-management concept. Moreover, it is strongly linked to the concept design because BIM should start at the design phase to allow the integration throughout the project life cycle.

**Figure 5 – (a) Strategic diagram Subperiod 2010-2012 (b) Thematic networks related with PROJECT-MANAGEMENT**

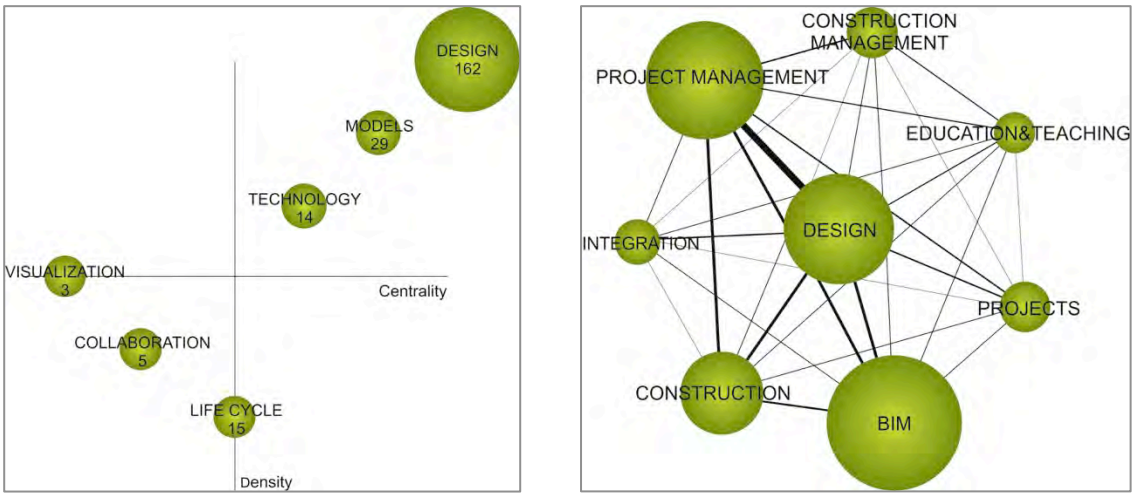



(a) (b)

In the 2010-2012 period (Fig. 5 (a)), project management continues being a motor cluster. The results are similar to the previous period, so it reinforces the application of BIM and sets the foundations of this tool in the project management domain.

In the Fig. 5 (a) appears an interesting emergent concept: education & teaching. According to Taiebat& Ku (2011), academic training, to professionals, workers and enterprises is essential in order to have an effective management of resources and to increase the profitability. In this sense, training may be able to obtain optimum results for its own benefits (ENGINEERS AUSTRALIA, 2012). .

**Figure 6 – (a) Strategic diagram Subperiod 2013-2015* (b) Thematic networks related with DESIGN**




(a) (b)

In the last analyzed period 2013-2015 (Fig. 6 (a)), the motor concept is design. Obviously, in its thematic networks (Fig. 6 (b)) can be observed the strong relation with the previousmotor concepts: BIM, Project management and integration and education and teaching.

In this period, the collaboration concept appears as emergent cluster in the strategic diagram. As mentioned in the introduction, collaboration is one of the main objectives to be achieved with the application of BIM in the project management (HALFAWY & FROESE, 2007; WEIMING et al., 2009;HANNELEet al., 2012). Then, the emergence of this concept in this last period may be due to the first results obtained with the research on BIM

The maintenance phase is the longest period in the building life cycle and therefore BIM becomes as important as an actual laboratory of the performance of building, its installations and its users (BECERIK-GERBER et al., 2012; HANNELE et al., 2012).

The BIM application areas, in the project life cycle, according to the project phase are the following:

- Design phase: Site analysis, Analysing design options, 3D presentation and Cost estimating(JONES, 2009; HANNELE et al., 2012).
- Construction phase:Clash detection, Schedule simulation, Quantity takeoff, Visualization and Safety monitoring (SAURIN et al, 2004; KAMARDEEN, 2010; BANSAL, 2011, ZHOU et al, 2012).

- Maintenance phase: Energy simulation, other performance simulations, Facility management and Emergency management (HANNELE et al., 2012; KIM & ANDERSON, 2013;PILEHCHIAN et al., 2015).

## 4. Conclusions

During last decade, BIM has attracted much attention in the AEC domain. BIM has mainly been widely employed in design organizations in order to allow collaboration between participants. Although BIM is a useful tool for facilitating design processes, the expected benefits of BIM throughout the project lifecycle have not yet been fully realized.In this regard, BIM is adopted in the design, construction and operational phases in diverse application areas, as for example, site analysis, cost estimation, clash detection,energy simulation, safety monitoring, planning, emergency management, etc.

The fragmented nature of AEC projects has led to the separated application of BIM in different phases of the project life-cycle, so it remains an interoperability problem. Despite these disadvantages, through the analysis of this proposal, it can be seen as BIM is envisioned to play an important role in order to integrating design, construction and facility management processes throughout the project life-cycle.

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