

# TOWARDS THE INTEGRATED ADOPTION OF BLM AND DT IN AECO-FM SECTOR: A SCIENTOMETRIC APPROACH

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The Architecture, Engineering, Construction, Operation and Facility Management (AECO-FM) industry presents a well-known discrepancy in terms of productivity and digitalization compared with other sectors. The introduction of building lifecycle management (BLM) could lead to several benefits covering all the phases of the building lifecycle (BLC) and enabling the implementation of a model-based integrated management system. Nevertheless, its adoption is far from being spread across the construction field and the case studies in the existing literature present several criticalities related to the adopted technologies and policies which hinder the complete development of a BLM system. To overcome these obstacles, digital twins (DTs) could be exploited to enhance the collaboration among actors, preserving the integrity of data, and offering a multidisciplinary environment to carry out realistic simulations. The purpose of this research is to conduct a scientometric analysis to evaluate the relationships between the topics of BLM and DT in the AECO-FM sector. The most common key studies and patterns are identified by processing bibliometric metadata. The most investigated topics related to BLM and DT are system design, system management, and Building Information Modeling (BIM) applications. The analysis reveals a gap regarding the connection between BLM and DT, identifying a potential research area that is currently unexplored in the academic field. The integrated adoption of these topics could contribute to promoting a holistic approach in the built environment by preserving data consistency, reducing information loss between design and construction phases, and strengthening connectivity among the actors involved in the process.

*Keywords:* Digital twin, Building lifecycle management, Product lifecycle management, AECO-FM industry, Model-based approach, Management system, Scientometric analysis.

## 1 INTRODUCTION

Building lifecycle management (BLM) refers to a strategic and holistic approach to integrating and handling the different stages related to the processes of a construction project lifecycle (Di Biccari *et al.* 2018). The acronym originates from the concept of product lifecycle management (PLM) and its successful implementation in the manufacturing industry. In fact, the PLM approach showed significant benefits in integrating the components of people, processes, and business information in order to provide a comprehensive and across-the-board system (Li *et al.* 2021).

In the Architecture, Engineering, Construction, Operation and Facility Management (AECO-FM) sector, BLM aims to minimize costs and enhance efficiency by optimizing the building

procedures during the design, construction, operation, and maintenance phases. As a result, BLM affects, at least indirectly, all the aspects of a project and the information related to it from the beginning to the end (Yitmen *et al.* 2021).

The management of such a quantity of data should be effective, real-time, consistent, and automated. This might result to be problematic if not supported by an appropriate system. Digital twin (DT) could offer an interesting opportunity to pursue a BLM approach by preserving data consistency, reducing information loss, and strengthening connectivity among the actors involved in the process. A digital twin (DT) is defined as a digital representation of a real element in which the latter and its digital counterpart are synchronized (ISO 2021). DTs could bring numerous benefits to the AECO-FM industry including analytics, simulations, a real-time updated interface, and visualization tools (Alizadehsalehi and Yitmen 2023) to improve the management of people and procedures in compliance with BLM principles. Nevertheless, the literature concerning the combined adoption of BLM and DT is quite limited and real applications are almost non-existent.

This paper first analyzes the existing studies related to the integrated adoption of BLM and DT in the building sector through a scientometric analysis, followed by a brief literature review to underline the main issues. Finally, the last section discusses the conclusions and potential further developments of the research.

## 2 METHODOLOGY

The bibliometric analysis was conducted in November 2022 querying the Scopus database. The study was carried out following the standard process of a systematic literature review (Shamseer *et al.* 2015). The following criteria were adopted to perform the analysis: only available full-English documents were considered; the search was limited to articles and conference papers in the final stage of publication; logic keyword strings were defined by using Boolean operators (e.g., “AND” and “OR”) and wild characters (e.g., the asterisk “\*”) to refine the output queries of the database. Figure 1 depicts the list of keywords used to query the database, allowing the selection of a list of publications and related meta-data matching the correlation between BLM and DT in the AECO sector. The software BiblioShiny (Aria and Cuccurullo 2017) and VOSviewer (Van Eck and Waltman 2011) were used to analyze and provide relevant data visualizations regarding the topics of the research. Scientific production, most relevant keywords, and theme evolution were investigated.

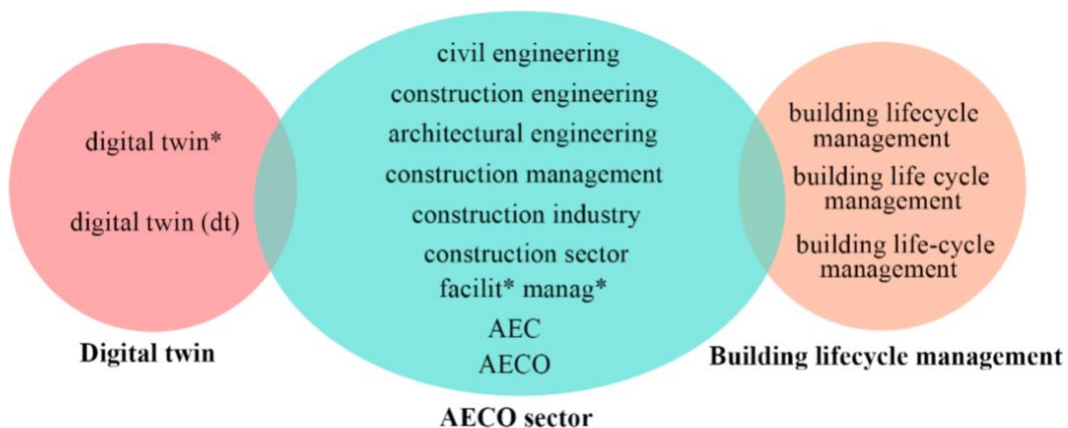


Figure 1. Visualization of the investigated topics through a Venn diagram. Software: BiblioShiny v. 4.0.

### 3 SCIENTOMETRIC ANALYSIS

#### 3.1 Scientific Production

Considering the yearly scientific production shown in Figure 2, there has been a significant rise in interest in BLM and DT themes in recent years. An annual growth rate of 30.03% was recorded. In particular, 97% of the analyzed studies were published after 2016, the 83% of which have been released in the period 2020-2022.

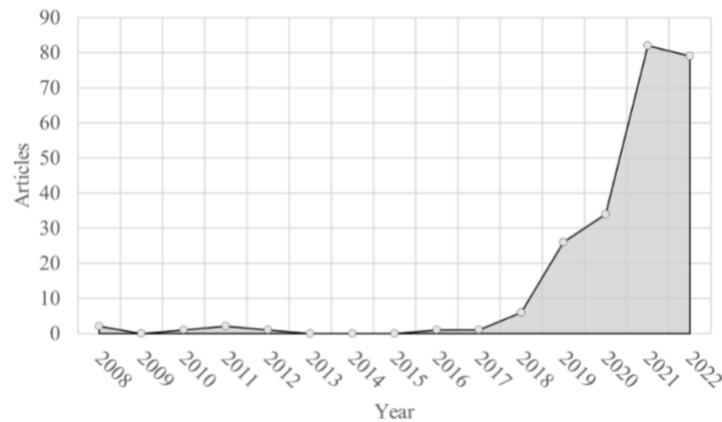


Figure 2. Annual scientific production concerning BLM and DT. Software: BiblioShiny v. 4.0.

#### 3.2 Co-Occurrence Keywords Network Map

The co-occurrence keywords network map, shown in Figure 3, was obtained using VOSViewer (Van Eck and Waltman 2011). Circles are associated with the number of occurrences of a specific word while the lines' thickness represents the strength related to the connections. In order to display the principal themes only, words associated with 12 or fewer occurrences were excluded from the visualization.

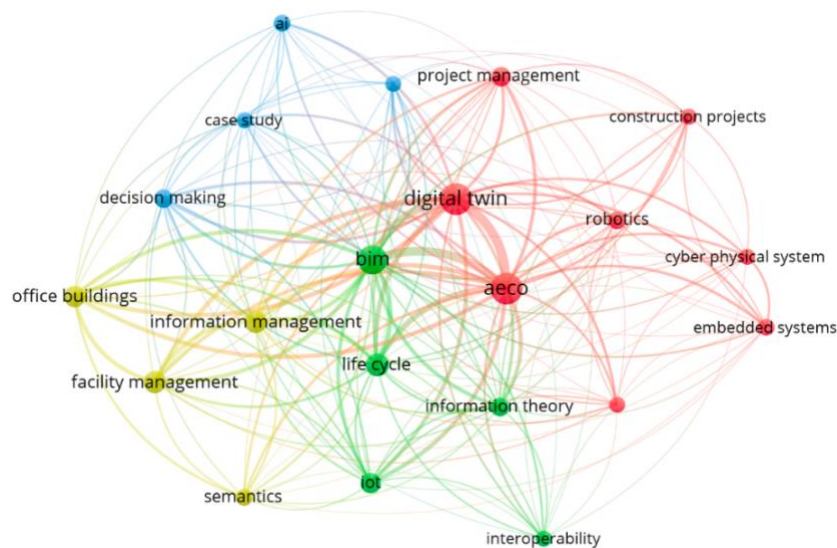


Figure 3. Co-occurrence keywords network map. Software: VosViewer v. 1.6.18.

According to the map, the most often used terms are DT, AECO, and BIM (154, 151, and 115 occurrences, respectively) followed by life cycle and information management (51 and 46 occurrences). Four main clusters are identified: a yellow one, a red one containing the words DT and AECO, a green one concerning the BIM topic, and a blue one located in the upper left.

The red cluster seems to be the most influential and significant concerning the study in which DT and BLM are mentioned. In this group, the DT topic is connected with the theme of Robotics and Project management while the embedded systems are more related to the AECO sector topics. Considering the green cluster, the BIM and Life cycle topics are close and linked. Life cycle, which is also connected with AECO, does not seem to be strongly correlated with DT. The other two groups shown by Figure 3 are reported on the left side of the graph. Both the yellow and blue clusters are linked to the red one through the BIM cluster where the main connections are visible. This underlines a strong relationship between themes such as FM (facility management), Information management, and BIM through which the DT theme comes up. On the other hand, the map does not show the keyword BLM despite being in the string to query the Scopus database. Consequently, there seems to be a weak semantic proximity of the topic BLM with the other investigated topics in the AECO sector.

### 3.3 Thematic Map

To provide an overview of the temporal evolution of the analyzed topics, a thematic map was produced (Figure 4). According to the scientific production (Section 3.1), three time slices are considered for the analysis as follows: 2008-2016, 2017-2019, and 2020-2022. In addition, a thesaurus was introduced to replace similar keywords.

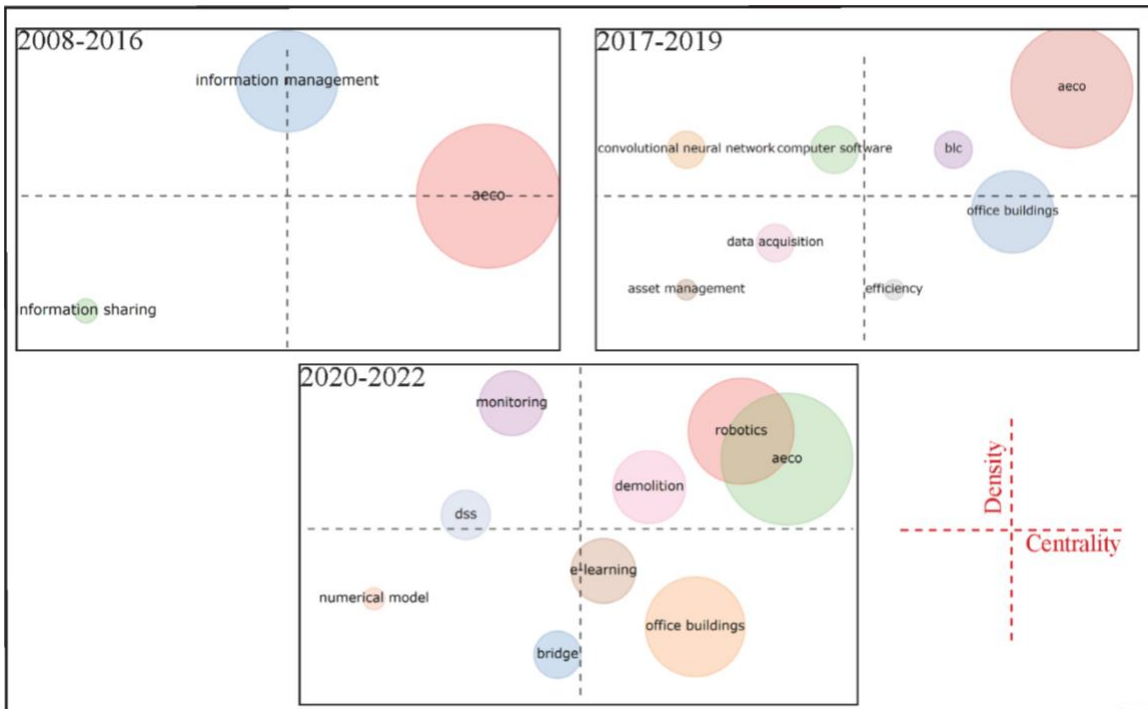


Figure 4. Thematic bivariate map for three time slices. Software: BiblioShiny v. 4.0.

Figure 4 displays three two-dimension graphs in which Callon centrality (x-axis) and Callon density (y-axis) are represented. Centrality corresponds to the overall relevance of a theme in the study considered while density is directly associated with the maturity level of the topics. Moreover, the size of the bubbles representing the examined subject is linked to their relative relevance to the others. In the first time slice (2008-2016) only three topics are shown: AECO, information management, and information sharing. The latter, which is located in the lower left part, appears to be poorly investigated and marginal while AECO-connected themes were more relevant to the literature. From 2017 to 2019, the depicted topics change drastically; in fact, six new terms are represented. In this graph, BLC is relevant and central in the cluster for the literature while AECO is characterized by a high centrality value. On the other side, asset management seems to be the most unexplored topic during this period. The third graph concerning the last two years denotes a prevalent interest in the AECO and in the robotics sector which are widely investigated. Even new themes associated with a low centrality such as monitoring or DSS (decision support system) come out from the analysis resulting in a total of nine themes displayed.

#### 4 LITERATURE REVIEW

This section aims at providing a brief literature review concerning the adoption of BLM in the AECO-FM sector through the use of DT.

Several studies have demonstrated the potential benefits of BLM in the construction sector underlying that it may help to reduce the environmental impacts of construction projects, while also improving their economic performance, quality, safety, and efficiency of the whole process.

However, there are some obstacles associated with BLM implementation which are widely documented in the literature and may be categorized into three groups: process-based issues (related to the struggle of modifying old procedures), technology-based issues (regarding the lack of software available on the market), and policy-based issues (considering the lack of standards during the construction process) (Jupp 2013). To overcome these difficulties, DT could be exploited to enhance the collaboration among actors, preserving the integrity of data, and offering a multidisciplinary environment to carry out realistic simulations (Alizadehsalehi and Yitmen 2023). In fact, a series of applications shows that DT has successfully achieved specific goals such as the reduction of energy needs or the improvement of users' comfort inside the environment as well as the productivity increase related to the procedures.

On the other hand, some criticalities and challenges concerning the feasibility of such implementation arose. In particular, DT systems are complex and resource-intensive to exploit requiring considerable investments in hardware, software, and training. Also, the privacy and security concerns related to DTs are being investigated by researchers (Boje *et al.* 2020).

Nevertheless, the studies concerning the connection between the topics of DT and BLM are quite limited and a significant gap regarding the lack of case studies affects the literature. In fact, most of them do not consider all the phase of BLC or present only a theoretical model that should be validated through a real application (Yitmen *et al.* 2021). For this reason, a general perspective to evaluate the real efficiency of a DT system through the BLM principle is still undefined.

#### 5 CONCLUSIONS

The study investigated the correlation between DT and BLM topics in the AECO-FM sector through a scientometric analysis. The first part of the research brought attention to the annual scientific production related to the investigated topics showing a clear surge of interest from the academic community. In particular, more than 80% of the studies were released from 2020 to 2022 while less the 3% were published before 2017. The second part examined the most relevant



keywords connected to DT and BLM studies through a co-occurrence network graph. DT, AECO, and BIM are by far the most often used terms with more than a hundred appearances. The connection between DT, AECO, and BIM appeared to be the strongest and two out of four clusters are connected to DT through BIM which thus represents an important topic in the scientific literature. On the other hand, the topic BLM does not seem to be among the most relevant topics in the investigated knowledge domain. The third part covered the temporal evolution of the topics considering three different time slices (2008-2016, 2017-2019, 2020-2022). A thematic bivariate map for each period allowed for tracking the density and centrality of the topics. The number of themes increased during the years and AECO gained centrality and relevance in the academia.

A brief literature review on the investigated topics was also conducted. The literature review highlighted the need to evaluate the real potential of such an integrated adoption of BLM and DT through real case studies applications that are currently almost inexistent. These could contribute to promote a holistic approach in the built environment by preserving data consistency, reducing information loss between design and construction phases, and strengthening the collaboration among the actors involved in the process.

In conclusion, considering the problems related to BLM use and the possible benefits that DT might introduce, both the scientometric analysis and the literature review highlighted the need to further study, analyze, and develop models aiming at promoting the integrated use of DT and BLM in the AECO sector.

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