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BIM in Civil Engineering Disciplines: A Scientometric Review (2005–2024)

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Abstract

This scientific study analyzes in a global overview the evolution and opportunity areas of the Building Information Modeling (BIM) methodology applied in the main disciplines in civil engineering; hydraulic, structures, systems planning and transportation, sanitary and environmental engineering, construction and geotechnics. Evaluates 3,180 documents covering temporarily from 2005-2024. The results show an exponential growth of publications from 2012, as well as a remarkable interest in China in research and application of the methodology. The analysis of BIM dimensions showed that 3D and 7D are the most recurring. Although the subject has evolved, challenges and knowledge gaps remain in the practical field; some disciplines such as geotechnics and hydraulics while developing new knowledge reflect it in case studies while others maintain a mostly theoretical approach. Finally, the analyses of co-occurrence of terms and of co-citation revealed the conceptual evolution of the field, as well as the theoretical foundational documents that support the current relevance.

Keywords: BIM, scientometric, civil engineering

Resumen

Este estudio cienciométrico analiza de forma global la evolución y áreas de oportunidad de la metodología Building Information Modeling (BIM) aplicada en Ingeniería Civil y sus principales disciplinas; hidráulica, estructuras, planeación de sistemas de transporte, ingeniería ambiental y sanitaria, construcción y geotecnia. Evalúa 3,180 documentos comprendiendo temporalmente del 2005-2024. Los resultados muestran un crecimiento exponencial de publicaciones a partir de 2012, además de un destacable interés en China en investigación y aplicación de la metodología. El análisis de las dimensiones BIM mostró que 3D y 7D son las más recurrentes. Aunque la temática ha evolucionado, persisten retos y brechas de conocimiento en el ámbito práctico; algunas disciplinas como geotecnia e hidráulica a la par que desarrollan nuevo conocimiento lo reflejan en casos de estudio mientras que las demás mantienen un enfoque mayormente teórico. Finalmente, los análisis de coocurrencia de términos y de cocitación revelaron la evolución conceptual del campo, así como los documentos fundacionales teóricos que sostienen su relevancia actual.

Palabras Clave: BIM, cienciométrico, ingeniería civil

1. Introducción

Building Information Modeling (BIM) is a collaborative methodology that has transformed the planning and execution of projects in architecture and civil engineering. It reduces design errors across disciplines and optimizes time and resource use (Liu, 2019). Its relevance has led to many studies that analyze implementation requirements and benefits (Faisal, 2022). Systematic reviews have also positioned BIM as a central component of Construction 4.0, understood as the convergence of industrial production, cyber-physical systems, and digital technologies, that together shape a digital construction environment (Begić, 2021).

Various investigations have documented the applications of BIM in the architecture, engineering, and construction (AEC) industry, identifying its main uses and limitations (Saieg, 2018). Scientometric analysis have detailed strands of knowledge development around this methodology and identified the most relevant authors (Liu, 2019). Although, these reviews and analyses offer broad overviews of the AEC industry, no specific study has addressed the impact and development of BIM across the different areas of civil engineering.

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Table 1. Comparative review of the literature [Zhao, X., 2017; Zhong, B., Wu, et. al., 2019; Santos, R., et. al.,2017, Li, X., et. al., 2017, Wen, Q.-J., et. al., 2021].

No.	1	2	3	4	5	6
Review	A scientometric review of global BIM research: Analysis and visualization, Automation in Construction, Volume 80.	A scientometric analysis and critical review of construction related ontology research, Automation in Construction.	A scientometric Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015, Automation in Construction,	A scientometric Mapping the knowledge domains of Building Information Modeling (BIM): A bibliometric approach, Automation in Construction.	A scientometric The progress and trend of BIM research: A bibliometrics-based visualization analysis, Automation in Construction.	Building Information Modeling in Civil Engineering Disciplines
Year	2017	2019	2017	2017	2021	2026
Authors	Xianbo Zhao	Botao Zhong, et al.	Rúben Santos, et al.	Xiao Li, et al.	Qing-Jie Wen, et al.	Ivan Felix, et al.
Objective	To map global research on BIM within the time period 2005–2016.	To review ontological research published mainly in the Scopus database from 2007 to 2017.	To conduct a bibliometric analysis and a review of the existing literature on BIM, focusing on 2005–2015.	Analysis of bibliographic records through a thematic search and a search via citation links within the Web of Science database.	Co-citation, co-word, and cluster analyses for data processing within the Web of Science database.	This study analyzes the evolution and research foci of BIM to identify trends and gaps within specific civil engineering areas
Methodology	Scientometric review, complemented with co-author, co-word, and co-citation analyses within the Web of Science database.	Scientometric review, complemented with co-author, co-word, co-citation, cluster analyses, and critical review within the Scopus database.	Literature review and quantitative bibliometric analysis method within the Web of Science database.	Analysis of bibliographic records through a thematic search and a search via citation links within the Web of Science database.	Co-citation, co-word, and cluster analyses for data processing within the Web of Science database.	Scientometric review, complemented with the PRISMA-ScR methodology, co-word, co-citation, cluster analyses, and critical review within the Scopus database.
Variations and limitations	614 articles were reviewed. The studies analyzed are within the period 2005–2016. The study is situated within the construction domain.	199 articles were reviewed. The studies analyzed are within the period 2007–2017. It is an ontological analysis, in the construction area.	381 articles were reviewed. The studies analyzed are within the period 2005–2015. It is a bibliometric analysis, developed within the construction area.	1,874 articles were reviewed. It is a bibliometric analysis. The studies analyzed are within the period 2004–2015, is developed within the construction area.	1,369 articles were reviewed. The studies analyzed are within the period 2002–2012. It is a bibliometric analysis, within the AEC industry.	3,180 articles were reviewed. The studies analyzed are within the period 2005–2024. It is developed across all areas of civil engineering.

To illustrate this gap, previous studies were reviewed. Five scientometric and bibliometric analyses were identified that map knowledge development around BIM. Table 1 summarizes their objectives, methods, analysis periods, and main limitations.

1.1 Research Questions and Objective

Based on the preceding discussion, this study proposes the following research question:

- What are the asymmetries in the apparent maturity of BIM knowledge between the various disciplines of civil engineering and what factors could explain the delay in those areas where there is less publication data?
- To what extent does scientific production on BIM in civil engineering manage to bring conceptual development into practical cases, and how does this transfer vary according to the applied BIM dimension (from 1D to 7D)?

Therefore, the objective of this review is to analyze BIM research in civil engineering through data analysis. The aim is to identify the disciplines with the most progress, those that remain underdeveloped, and the extent to which theoretical concepts are becoming practical applications on-site in six key areas of civil engineering: planning and transportation,

hydraulics, structures, geotechnics, sanitary and environmental engineering, and construction. The purpose is to provide a statistical overview of the impact and evolution of BIM in these fields, thereby laying groundwork for future research.

2. Methods and Materials

To assess the level of development of the BIM approach in the different areas of civil engineering, a scientometric analysis was conducted. This type of study applies quantitative techniques to examine the evolution, structure, dynamics, trends, and interrelationships of scientific research in a specific field of knowledge, based on the available academic output (Michán, 2013).

Since this type of analysis involves managing a large volume of information, the PRISMA-ScR methodology was adopted, which is widely used for scoping systematic reviews. This tool enables transparent organization of the process of identifying, selecting, and including publications, ensuring consistency in the construction of the database. Previous studies have shown yields solid and reproducible results (Pereira, 2021).

To support the screening and filtering stages of the articles, the reference management software Rayyan (2024) was used. This software facilitates the removal of duplicates, classification of documents, and peer review (Ouzzani, 2016).

2.1. Search Strategy

The Scopus database was selected as the primary source of information due to its broad coverage of scientific publications in engineering and its ability to accurately structure metadata, which supports detailed bibliometric and scientometric analyses. Scopus was chosen because it has been consistently used in similar BIM studies (Ozturk, 2021; Locatelli, 2021).

The search strategy was executed in December 2024 and included articles that contained the terms “BIM” or “Building Information Modelling” in the title or keywords. The abstract field was intentionally excluded because many articles tangentially reference BIM without addressing it as a central topic. The search was limited to the field of engineering, with no language restriction, and included all publications available up to the specified date.

Duplicate documents were subsequently removed using Rayyan. In the first screening phase, two reviewers assessed the articles for their relevance and direct focus on BIM applied to civil engineering, following a procedure similar to that reported in previous studies (Li, 2020). For an article to be included, it had to meet two conditions:

1. Develop a BIM application within civil engineering.
2. Present results that could be classified in at least one of the following areas: planning and transportation, hydraulics, structures, geotechnics, sanitary and environmental engineering, or construction (according to the classification of civil engineering areas proposed by UNAM (UNAM, 2023).

To validate the clarity of the inclusion criteria, both reviewers conducted an initial test on 30 documents, classifying them as “yes,” “no,” or “maybe” to generate a ground truth. The results were compared in a confusion matrix, and the Kappa index was calculated, disagreements between reviewers were resolved until a value of Kappa reached 0.80, which is considered acceptable for this type of study.

Articles classified as “maybe” in this first phase were subjected to full-text review to determine their final inclusion or exclusion. From this process, the final database of articles analyzed in this study was constructed. Figure 1 visually summarizes the phases of the procedure followed, including the initial identification of documents, removal of duplicates, exclusion after the first review, full-text review, and finally, the selection of studies deemed suitable for analysis.

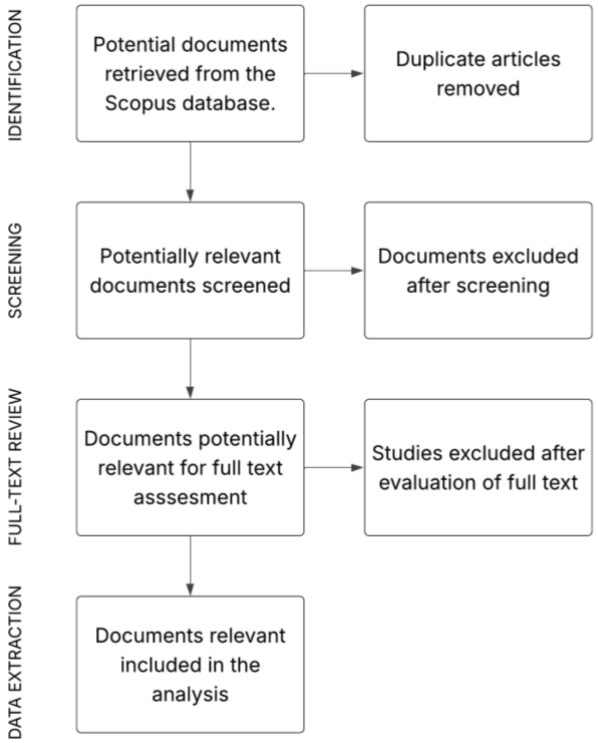


Figure 1. Flowchart of the Article Selection Procedure

2.2. Data Extraction

Once the database was finalized, relevant information was extracted from each article in order to map the development of the BIM methodology in civil engineering. For this purpose, a second reading of titles and abstracts was conducted to collect specific variables. The process was supported by Google Electronic Forms, which enabled systematic data recording and storage. The extracted variables are organized into six main categories.

Table 2. Categorization of Extracted Variables

Category	Variable	Description / Purpose
Bibliographic Data	Year of Publication, Document Type, Source	Identify the temporal evolution and dissemination type of the research.
Keywords	Keywords Associated with the Article	Analyze thematic trends and term co-occurrences.

Country / Region	Country and Region of Origin of the Research	Map the geographical development of BIM in civil engineering.
Civil Engineering Area	Hydraulics, Structures, Systems, Planning and Transportation, Sanitary and Environmental Engineering, Construction, Geotechnics	Classify each article into one of the six main areas of civil engineering.
Scope of Results	Theoretical vs. Practical	Identify the maturity level of BIM application (experimental environment vs. real project use).
BIM Dimension	1: Idea, 2: Sketch, 3: Modeling, 4: Time, 5: Cost, 6: Sustainability, 7: Operation and Maintenance	Determine the most represented BIM dimensions in the studies.

The classification of civil engineering areas was based on curricula from universities in Mexico and the United States, which allowed for the delimitation of six main disciplines. Although there are differences in subdivisions depending on the institution, this categorization consistently reflects the fundamental fields of civil engineering.

The analysis was designed to describe the evolution of BIM use in civil engineering and to identify trends, gaps, and research opportunities. To achieve this, four complementary approaches were applied:

Evolution and Global Scientific Output. The publication trajectory on BIM in civil engineering was examined, considering the annual volume of documents, publication types, and the general subject areas in which they are categorized.

Actors and Collaboration Networks. The most productive authors, institutional affiliations, leading countries in publications, and top journals were analyzed, along with co-authorship and citation co-occurrence networks using VOSviewer.

Application in Civil Engineering Areas. Articles were classified according to six core disciplines (planning and transportation, hydraulics, structures, geotechnics, sanitary and environmental engineering, and construction), and the degree of development in each area and differentiating between theoretical and practical results.

BIM Dimensions and Research Approaches. The phases of the BIM cycle represented in the literature were examined (idea, sketch, modeling, time, cost, sustainability, operation, and maintenance), complemented by a co-occurrence analysis of terms to map the predominant thematic clusters.

3. Results

According to the methodological section, a total of 8,284 records were retrieved from Scopus, and 63 duplicates were removed using Rayyan. In the first screening based on titles and abstracts, 3,232 documents were included, 4,989 were excluded, and 66 were marked as uncertain for a second evaluation. In the third phase, those 66 documents were re-evaluated, and 52 were discarded. The final total of accepted articles was 3,180. Figure 2 summarizes the selection flow.

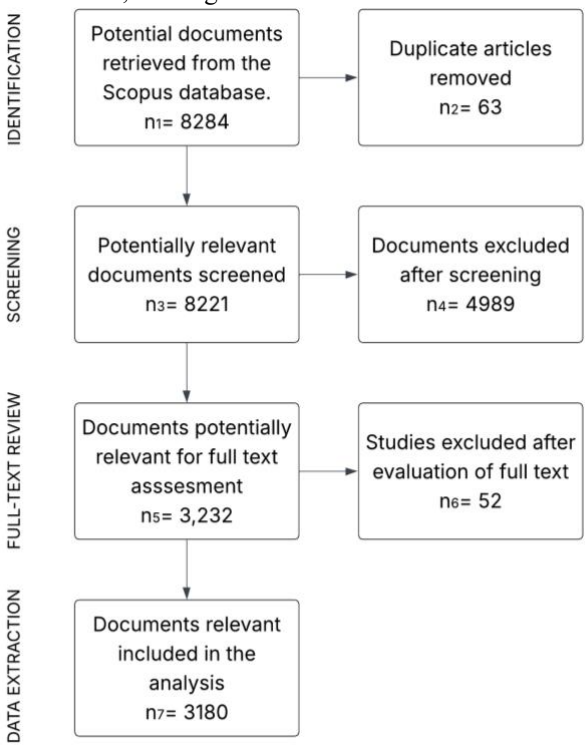


Figure 2. Flowchart of the Results from the Article Selection Procedure

The findings from the database analysis are presented in four sections: (i) global scientific production, (ii) actors and collaboration networks, (iii) application in civil engineering areas, and (iv) BIM research dimensions and approaches.

3.1. Temporal Evolution

The publication of works linking civil engineering with the BIM methodology began in 2005. As shown in Figure 3, the development of this research line was very slow during the early years. Between 2005 and 2016, publications in this area increased at a modest rate. However, starting in 2017, an exponential rise in the number of published documents on this topic can be observed. The year 2024 recorded the highest number of publications to date.

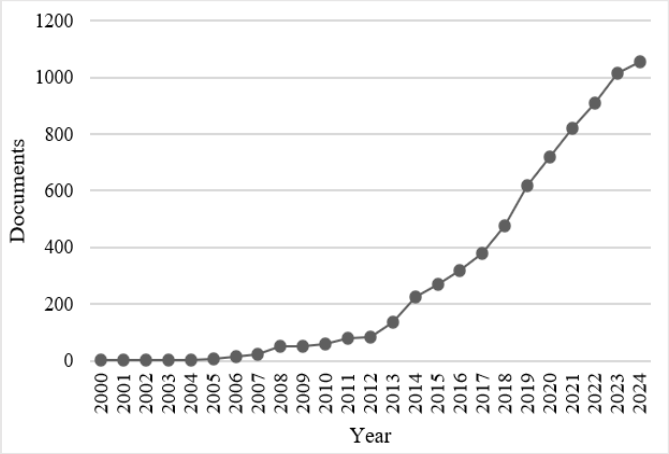


Figure 3. Documents by Year

3.2. Actors and Collaboration Networks

3.2.1. Most productive Authors

To identify the most prominent authors in the BIM–civil engineering intersection, a ranking was created based on the number of publications from the refined dataset. In total, 289 authors were recorded with at least one document; among them, 5 authors account for the highest publication output, as shown in Figure 4.

The count was conducted by author signature on each document (including co-authorships), with the aim of recognizing those who have contributed most consistently to the development of the field.

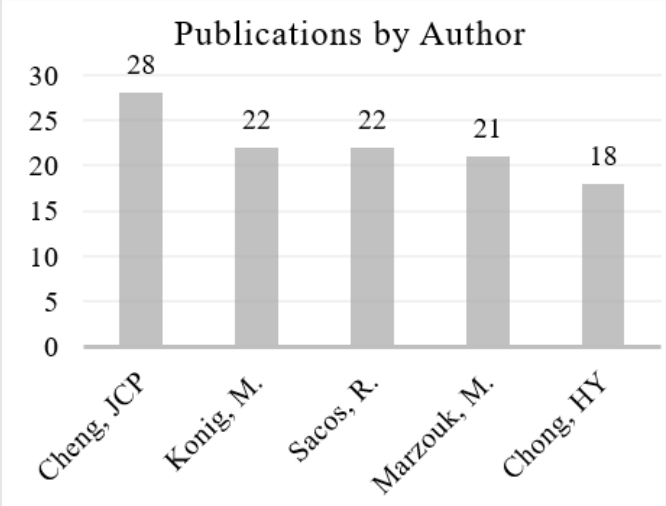


Figure 4. Publications by Authors

Additionally, the institutional affiliations and sponsoring entities with the highest publications volumes are presented in the corresponding sections of this chapter to contextualize the institutional contribution and financial support behind the most productive authors. Together, these results show a concentration of output within a small core of researchers, suggesting the presence of consolidated research groups and ongoing lines of work on the topic.

3.2.2. Collaboration Networks (Co-authorship / Co-citation)

To complement the ranking of the most productive authors (Figure 4), a bibliometric network of the most cited authors was constructed using VOSviewer, based on the refined Scopus database (Figure 5).

The network includes the 87 most relevant authors, selected using a minimum citation threshold of 320 citations. A temporal overlay visualization was applied, in which the nodes are color-coded by year: blue shades for authors whose citations are concentrated around 2017, and yellow shades for those around 2022.

The map reveals greater relevance of influential authors during the 2018–2020 period, as well as concentrations (clusters) that group together related lines of research and recurring collaborations. This representation not only highlights who the most frequently cited references are but also how they are interconnected within the BIM–civil engineering field.

The nodes with the highest degree centrality (i.e., the most connected authors) are located in the clusters on the right side of Figure 5, reflecting their role as bridges between research lines and their influence in driving multi-institutional projects.

The authors who have had apogee with greater antiquity are Cheng, Zhang, Teizer and Wang; it is visually from 2019 onwards, co-citation between authors began to soar, which

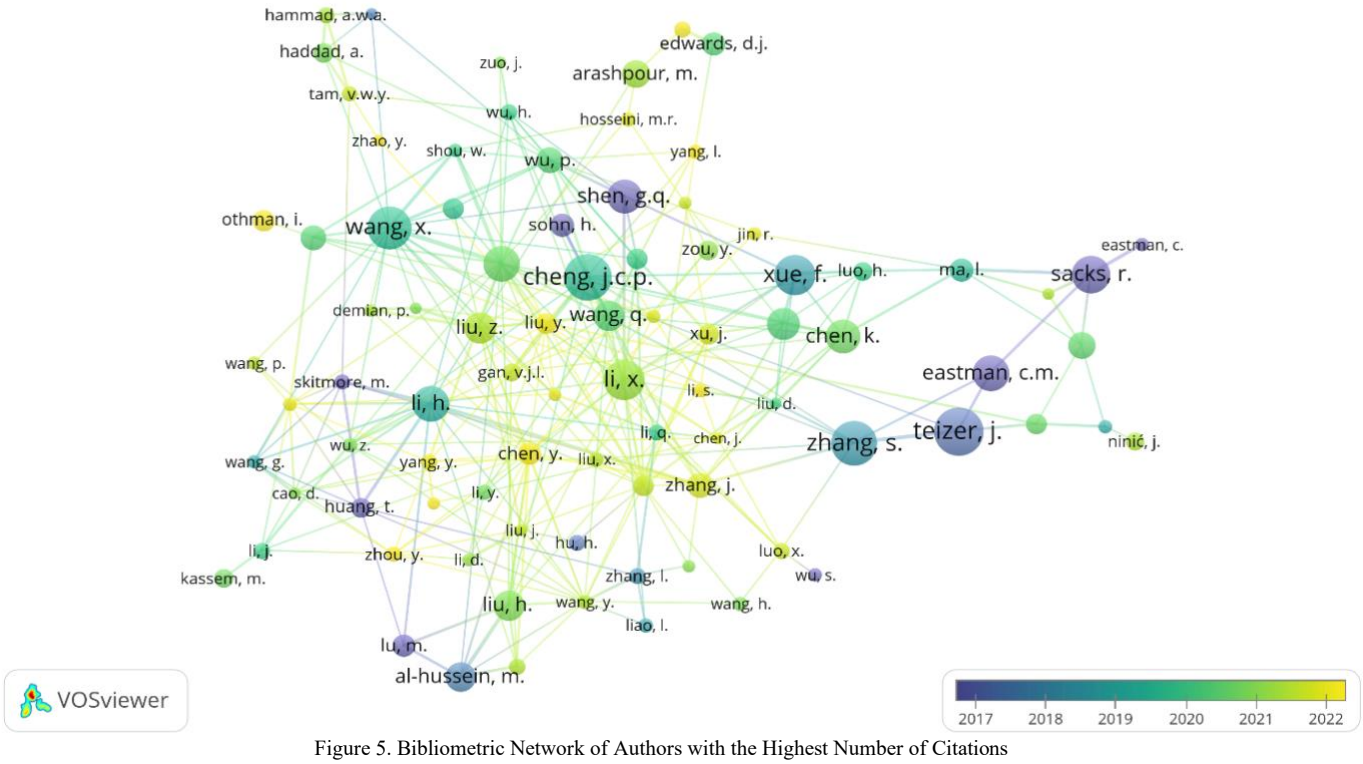


Figure 5. Bibliometric Network of Authors with the Highest Number of Citations

indicates that the bases of the first authors have been cited to expand new investigations. They still rely on concepts from 5 to almost 10 years ago.

3.2.3. Institutional Affiliations

In the context of scientific communication, affiliation refers to the institution with which an author declares an academic or professional relationship (Slafer, 2009). To identify the institutional origin of the output, the affiliations of all documents included in the refined database were analyzed. In total, 248 affiliations were recorded. Figure 6 presents the 5 institutions with the highest number of documents, showing a clear concentration in Chinese institutions.

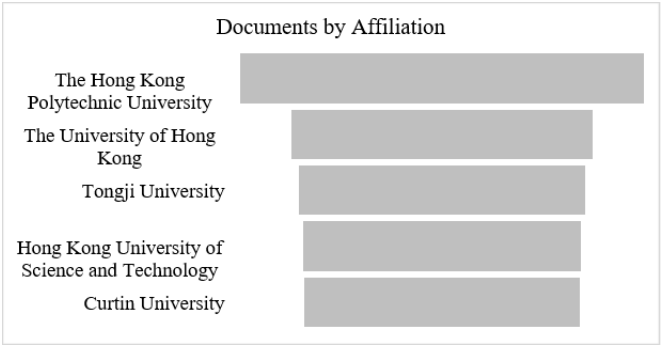


Figure 6. Documents by Affiliation

3.2.4. Leading Countries

Publications from 102 countries were identified, highlighting the wide geographical distribution of research in this field. Figure 7 shows the 10 countries with the highest number of documents, with China in first place, followed by the United States and the United Kingdom, both with similar publication volumes.

This distribution reflects a strong concentration of scientific production in economies with significant investment in R&D and active agendas in digital construction.

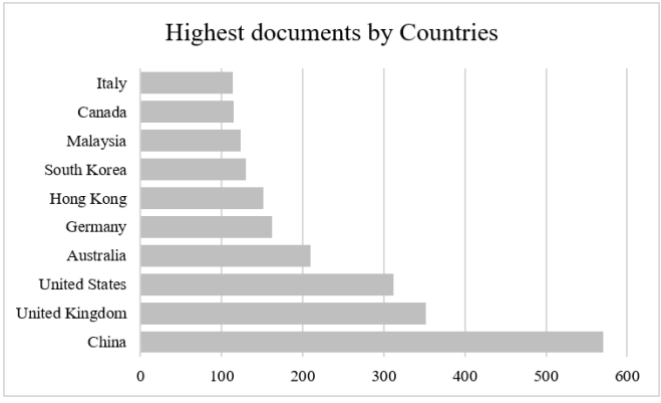


Figure 7. Documents Published by Country of Origin

3.3. Application in Civil Engineering Areas

3.3.1. Classification by Disciplines and Subdisciplines

To answer the research questions, the articles were classified by area and subarea. This organization allows for the identification of which disciplines show the greatest development of knowledge and which ones lag behind. The results are presented in Table 3.

Table 3. Civil Engineering Areas and Subareas

Civil Eng. Areas	Total	Civil Eng. Subareas	Percentage
Structures	16%	Reinforced Concrete Structures	8%
		Masonry Structures	4%
		Steel Structures	10%
		Seismic Engineering	10%
		Bridges	31%
		Concrete Structures	12%
		None Specific (Structures)	25%
Systems, Planning, and Transportation	11%	Airports	5.9%
		Highways	28%
		Railways	28.3%
		Ports	2%
		Tunnels	12.6%
		None Specific (Systems/Transportation)	23.2%
Environmental	13%	Sustainable Buildings	52%
		Renewable Energy in Buildings	3%
		Facility Management in Buildings	20%
		Water Treatment Plants	1%
		Sustainable Engineering Projects	22%
		None Specific (Environmental)	2%
Hydraulics	2%	Groundwater Management	10%
		Hydraulic Structures Design	21%
		Urban Hydraulics	40%
		Coastal Engineering	8%
		Hydraulic Modeling	17%
		None Specific (Hydraulics)	4%
Construction	41%	Construction Management	40%
		Site Safety and Productivity	35%
		Construction Supervision	9%
		Project Management	5%
		None Specific (Construction)	11%
Geotechnics	2%	Dikes and Dams	4%
		Soil Dynamics	37%
		Pavement Structure	15%
		Soil Mechanics	36%
		None Specific (Geotechnics)	8%
Covers All Areas of Civil Engineering	15%		

Overall, construction concentrates the largest proportion of studies, establishing itself as the field of greatest interest among researchers. Structures rank second, with a smaller but still significant share due to the volume of contributions identified.

Within the structures category, shows the distribution by subareas and their respective percentages. Notably, bridges

account for approximately one-third of the knowledge generated in this category, followed by areas such as steel structures, concrete, and seismic approaches.

In planning and transportation systems, reveals a more balanced distribution among subareas; railways and highways appear as dominant themes. In contrast, port studies show lower representation, suggesting a potential opportunity to generate new knowledge.

In sanitary and environmental engineering, BIM emerges as an effective approach to integrate sustainability goals and energy efficiency. According to Table 3 the sustainable buildings subarea concentrates the largest number of studies, followed by facility management and other environmental lines.

Hydraulics is a fundamental discipline for social well-being, its relative presence in literature is lower compared to other areas. Nevertheless, there are valuable contributions, particularly with an emphasis on urban hydraulics, which underscores the importance of water resource management in urban environments.

In the construction category, Table 3 details the distribution by subareas. In addition to its quantitative weight, two research lines stand out: construction management and site safety and productivity, which highlight BIM's potential to optimize resources, improve control, and reduce risks in projects.

Finally, geotechnics appears among the areas with less relative development, making it a fertile ground for new applications. Table 3 shows that the identified production is mostly concentrated in soil mechanics and dynamics, along with specific topics such as pavements and retaining structures.

3.3.2. Scope of Results: Theoretical vs. Practical

To assess the level of maturity in BIM adoption, the articles were classified according to the nature of their contribution (theoretical or practical).

The analysis shows that 65% of the documents correspond to theoretical research, focused on the study or development of concepts and methods (often in experimental or simulation environments), while 35% report practical applications in real case studies.

Table 4. Civil Engineering Areas – Theoretical or Practical Results

Area	Theoretical (n)	Practical (n)	Total per Area (n)	% Theoretical	% Practical
Construction	871	432	1303	67%	33%
Structures	239	258	497	48%	52%
Planning and Transportation	417	66	483	86%	14%
Sanitary and Environmental Engineering	128	53	181	71%	29%
Hydraulics	26	26	52	50%	50%
Geotechnics	35	43	78	45%	55%
Articles Covering All Areas	351	235	586	60%	40%
Total	2067	1113	3180		

Although the practical share is smaller, it is not marginal and demonstrates BIM's applied utility in civil engineering projects, indicating a trajectory of transition from conceptual development toward broader adoption in professional practice.

To evaluate the maturity of BIM adoption by discipline, each civil engineering area was cross-referenced with the nature of the result (theoretical/practical). Table 4 summarizes the counts and proportions by area.

Overall, cross-disciplinary articles show the highest proportion of applied studies (86%), followed by Sanitary and Environmental Engineering with 71%. In contrast, Geotechnics shows the lowest level of practical application (45%), while Structures maintains a relative balance between theoretical (52%) and practical (48%) contributions.

The balance between theoretical and practical research serves as a key indicator of the development of BIM applications. Fields with a balanced distribution, such as Hydraulics, Geotechnics and Structures, demonstrate a healthy cycle where theoretical data are immediately validated in practice, a factor that could be the laws involved. Conversely, the heavy tilt toward theory in areas like Construction and Environmental Engineering reveals a significant adoption gap. This imbalance suggests that while academic knowledge advances rapidly on paper, practical implementation in the real world remains slow, leaving a vast amount of theoretical insight underutilized by industry.

3.3.3. BIM Dimensions and Research Approaches

The articles were classified by BIM dimension to identify which phases of the BIM lifecycle receive the most attention in the civil engineering literature.

For clarity, the following nomenclature was adopted: 1D (idea/concept), 2D (sketch/preliminary design), 3D (modeling), 4D (time), 5D (cost), 6D (sustainability), and 7D (operation and maintenance). The results are presented in Figure 8.

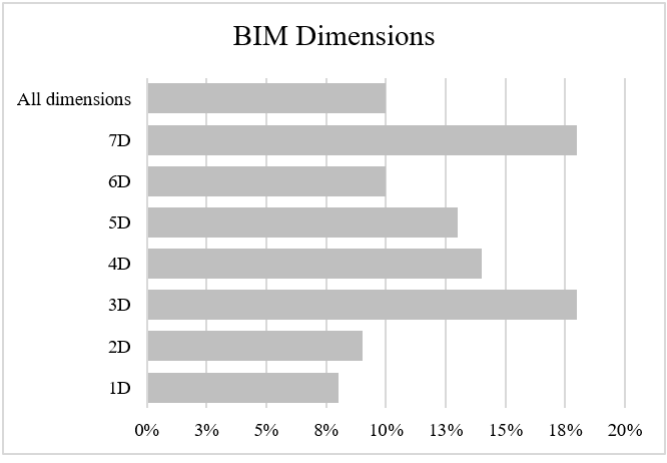


Figure 8. BIM Dimensions

It is observed that 3D (Modeling) and 7D (Operation and Maintenance) are the predominant dimensions within the analyzed set, suggesting two main areas of focus:

(i) the construction of digital representations of assets, and
(ii) their management during the operational phase.

In contrast, 5D (Cost) and 6D (Sustainability) show lower relative presence, indicating opportunities to further explore the integration of cost–time–sustainability within BIM research

3.3.4. *Term Co-occurrence*

To map research themes and trends, a term co-occurrence analysis was conducted using VOSviewer, based on the refined Scopus dataset (Figure 9). A total of 1,000 high-frequency keywords were integrated, applying: a minimum occurrence threshold of six, association strength normalization, and merging of synonyms and variants through acronym and equivalent name unification rules (e.g., "BIM" ≡ "Building Information Modeling"). A bibliometric network of keywords was obtained through this analysis.

The green cluster groups the conceptual core of BIM and directly related terms, such as platforms, interoperability, and information models. The blue cluster focuses on sustainability, including concepts such as LCA/LCC, energy efficiency, emissions, and certifications. The red cluster brings together digital tools and workflows, such as software, scripts, interoperability, and automation.

The remaining clusters articulate civil engineering areas and cross-cutting topics, including: Structures (inspection, bridges, SHM), Safety (H&S, risk management), Planning/Construction (4D/5D), and Operation/Maintenance (digital twin, FM).

3.4. *Discussion*

3.4.1. *Interpretive Overview of the Field*

Research on BIM in civil engineering shows sustained growth and an expanding thematic diversity, with engineering and computer science as its core axes, and a growing openness toward environmental and social dimensions (Zhao, 2017; Li, 2017). The observed concentration of core authorship aligns with previous findings on active and expanding scholarly communities (Zhao, 2022), and the centrality of certain editorial channels, such as Automation in Construction, has been consistently reported in the specialized literature (Ozturk, 2020; Kuai, 2023). Methodologically, the coexistence of mature lines and emerging fronts calls for prioritizing interoperability, standardization, and data governance over mere output counts, as these are critical for effective knowledge transfer into practice.

3.4.2. *Geographical and Temporal Dynamics*

The geographical breadth (over one hundred countries) coexists with marked asymmetries: China, the United States, and the United Kingdom lead in volume, partly due to public policies, R&D investment, and regulatory frameworks that promote adoption (Zhao, 2017; Liu, 2019). China's case may be linked to its rapid infrastructure growth and national strategies for digitalization of the construction sector (Li, 2020; Xu, 2020).

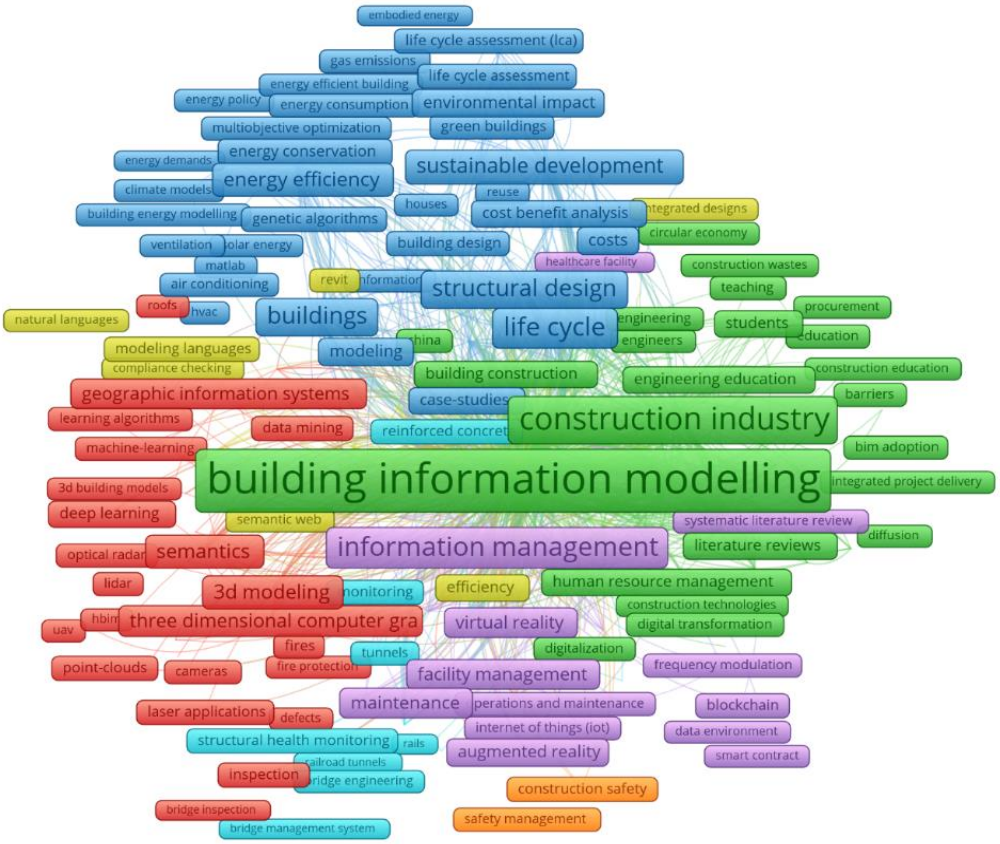


Figure 9. Bibliometric Network of Keywords

In terms of time, the 2005–2016 phase corresponds to early-stage adoption; from 2017 onward, publication output accelerates, consistent with the maturation of BIM platforms and increasing pressure for efficiency and sustainability (Santos, 2017; Bradley, 2016).

This evolution is also reflected in recent analyses highlighting the growing leadership of certain countries and the progressive expansion of the literature into new regions (Öztürk, 2020). The post-2017 leap marks a phase shift: from exploring "if it can be done" to documenting "how it's done" and "with what value."

3.4.3. BIM Dimensions: Focus and Opportunities

The dominance of 3D (modeling) and 7D (operation and maintenance) reflects dual interest in accurate representation and lifecycle asset management (Akram, 2019; Bradley, 2016). In contrast, 5D (cost) and 6D (sustainability) remain underrepresented, despite their influence on decision-making. The literature highlights the role of ontologies and standards in improving semantic interoperability and integration across dimensions (Zhong, 2019; Teng, 2022) and warns against the limitations of manual workflows due to issues of traceability and error propensity (Tam, 2022). To fully capture BIM's benefits, it is crucial to integrate it from early design stages through to operation and, where applicable, decommissioning (Zou, 2017; Aziminezhad, 2023). Additionally, cost management must be strengthened through value engineering approaches and systematic control (Lu, 2023; Ismail, 2016).

3.4.4. Application by Area: Concentration and Gaps

Construction concentrates the largest output, with emphasis on management and safety/productivity, where BIM supports resource optimization, risk prevention, and operational decision-making (Akram, 2019; Li, 2023).

In structures, the strong density around bridges suggests a specialized line with high value for transport infrastructure (Bradley, 2016). In sanitary environmental fields, the BIM–sustainability synergy is gaining traction (e.g., energy efficiency, environmental performance) (Lim, 2021).

Clear opportunities emerge in hydraulics, geotechnics, and port engineering, where the modeling and data complexity demand specialized libraries, validation protocols, and pilot studies with comparable metrics. This is not a matter of relevance, but rather of technical complexity, which requires tighter collaboration frameworks.

3.4.5. Keywords and Thematic Evolution

The term co-occurrence analysis confirms a central BIM cluster, alongside themes tied to sustainability, digital tools, structures, and safety. Temporal overlay suggests a recent shift toward operation, energy efficiency, and digital twins, in line with the field's growing maturity.

In addition, new vectors of advancement are emerging: integration with AI/ML, IoT, and cyber-physical systems, which open up scenarios for advanced analytics and automated decision-making (Biswas, 2024).

Moreover, national case studies have identified thematic gaps (e.g., Malaysia: energy efficiency, lifecycle analysis, housing), which are useful for guiding local research agendas (Tanko, 2022).

3.4.6. Study Limitations and Validity

This study presents typical limitations: reliance on Scopus as the sole source, a search strategy focused on title/keywords (which reduces noise but may exclude peripheral studies), disciplinary classification based on expert judgment (which, despite validation, retains some subjectivity), and a temporal cut-off linked to the extraction date. These constraints do not invalidate the trends identified but do narrow their interpretation. Future work could triangulate across databases, incorporate impact indicators (e.g., citations, country/institution networks), and apply normalizations (e.g., by population or R&D investment) to enrich international comparisons.

4. Conclusions

This work offers a structured overview of the development of BIM in civil engineering, articulating evidence on scientific output, key actors, application areas, and research dimensions and approaches, and proposing an integrated interpretation that connects academic dynamics with professional practice. Based on the findings, the following conclusions are drawn:

Consolidation and Phase Transition. The field has moved from exploratory adoption to a phase of broader implementation, where BIM is no longer treated as an isolated experiment but operates as the informational infrastructure for managing projects and assets.

Heterogeneous Maturity. BIM adoption varies across disciplines and purposes: consolidated practices (e.g., construction management and operation/maintenance) coexist with less mature fronts that still require standardization and applied evidence (e.g., cost and sustainability integrated into planning).

Role of Enabling Mechanisms. BIM's potential depends not only on tools but also on interoperability, data governance, and coordinated processes. Without these, the transition from model to decision-making is weakened.

Useful but Incomplete Thematic Concentration. The density of research in construction and structures has generated repeatable methodologies and clear lessons; the challenge is to transfer this maturity to areas with greater data/modeling complexity, such as hydraulics, geotechnics, and ports.

Lifecycle Value. The emphasis on modeling and operation highlights that BIM's value grows when viewed across the entire lifecycle of an asset or process not just during design. The integration of time, cost, and sustainability is the next logical step.

Ecosystem and Capabilities. A critical mass of authors, institutions, and editorial channels now exists. What determines impact is the ability to form consortia and develop professional profiles with expertise in data, standards, and performance analysis.

This has practical implications for project development, organizations, and public policy. For projects, it is advisable to prioritize use cases that connect time, cost, and environmental performance through comparable metrics and ensure traceability from the model to the decision. In organizations, the value does not stem solely from the adoption of new tools,

but from the implementation of data protocols, clearly defined roles, and informational continuity through to operation and maintenance. At the institutional level, public guidelines and mandates should promote open standards and performance-based procurement so that interoperability becomes an operational requirement rather than merely an aspirational goal.

In research, the next step is to turn conceptual mass into field-based evidence. Comparable study designs with baselines and outcome indicators are needed to close the gap between laboratory environments and real-world construction sites, particularly in underdeveloped disciplines such as hydraulics, geotechnics, or port engineering. It is also a priority to experiment with integrated 4D–5D–6D workflows and digital twins anchored in reliable operational data; to incorporate impact metrics (beyond volume) and international normalization standards; and to advance in the development of ontologies and discipline-specific object libraries that reduce semantic ambiguities and improve data quality.

This technical agenda requires training and capabilities that match its level of complexity. The integration of BIM should be transversal across academic curricula from design to operation with a strong emphasis on data, standards, lifecycle assessment, and evidence-based decision-making. Developing hybrid professional profiles capable of navigating between engineering, information, and management is essential to ensure that advances move beyond pilot implementations and scale up with rigor.

In summary, BIM is reaffirmed as a platform for better decision-making, not just for better modeling. Its real value will emerge where data is standardized, benefits are measured, and maturity is extended to underrepresented areas. The immediate priority is to apply with evidence, interoperate with rigor, and build teams capable of sustaining this transition over time.

Statement on the use of generative Artificial Intelligence and AI-assisted technologies

During the preparation of this manuscript, the authors used Gemini 1.5 Pro for grammatical and typographical editing of the document, as well as for the structuring, visual organization, and formatting of tables and data graphics. All content generated or suggested by the tool was reviewed and edited by the authors, who take full responsibility for the accuracy, originality, integrity, and scientific rigor of the final manuscript content.

References

Akram, R., Thaheem, M.J., Nasir, A.R., Ali, T.H. & Khan, S. (2019). Exploring the role of building information modeling in construction safety through science mapping. Safety Science, 120, 456–470. https://doi.org/10.1016/j.ssci.2019.07.036

Aziminezhad, M. & Taherkhani, R. (2023). BIM for deconstruction: A review and bibliometric analysis. Journal of Building Engineering, 73, 106683. https://doi.org/10.1016/j.jobe.2023.106683

Begić, H. & Galić, M. (2021). A systematic review of Construction 4.0 in the context of the BIM 4.0 premise. Buildings, 11(8), 337.

Biswas, H.K., Sim, T.Y. & Lau, S.L. (2024). Impact of Building Information Modelling and advanced technologies in the AEC industry: A contemporary review and future directions. Journal of Building Engineering, 82, 108165. https://doi.org/10.1016/j.jobe.2023.108165

Bradley, A., Li, H., Lark, R. & Dunn, S. (2016). BIM for infrastructure: An overall review and constructor perspective. Automation in Construction, 71, 139–152. https://doi.org/10.1016/j.autcon.2016.08.019

Faisal Shehzad, H.M., Binti Ibrahim, R., Yusof, A.F., Mohamed Khaidzir, K.A., Shawkat, S. & Ahmad, S. (2022). Recent developments of BIM adoption based on categorization, identification and factors: A systematic literature review. International Journal of Construction Management, 22(15), 3001–3013.

Ismail, N.A.A., Drogemuller, R., Beazley, S. & Owen, R. (2016). A review of BIM capabilities for quantity surveying practice. MATEC Web of Conferences, 66, 00042. https://doi.org/10.1051/matecconf/20166600042

Kuai, X., Liu, Y., Bi, M. & Luo, Q. (2023). Deciphering building information modeling evolution: A comprehensive scientometric analysis across lifecycle stages. Buildings, 13(11), 2688. https://doi.org/10.3390/buildings13112688

Li, X., Wu, P., Shen, G.Q., Wang, X. & Teng, Y. (2017). Mapping the knowledge domains of Building Information Modeling (BIM): A bibliometric approach. Automation in Construction, 84, 195–206. https://doi.org/10.1016/j.autcon.2017.09.011

Li, J., Afsari, K., Li, N., Peng, J., Wu, Z. & Cui, H. (2020). A review for presenting building information modeling education and research in China. Journal of Cleaner Production, 259, 120885. https://doi.org/10.1016/j.jclepro.2020.120885

Li, C.Z., Zhao, Y., Xiao, B., Yu, B., Tam, V.W.Y., Chen, Z. & Ya, Y. (2020). Research trend of the application of information technologies in construction and demolition waste management. Journal of Cleaner Production, 263, 121458. https://doi.org/10.1016/j.jclepro.2020.121458

Li, C.Z., Zhen, Y., Wu, H., Chen, Z., Xiao, B. & Tam, V.W.Y. (2023). The application of BIM in the AECO industry. Journal of Civil Engineering and Management, 29(3), 202–222. https://doi.org/10.3846/jcem.2023.18076

Lim, Y.-W., Chong, H.-Y., Ling, P.C.H. & Tan, C.S. (2021). Greening existing buildings through Building Information Modelling: A review of the recent development. Building and Environment, 200, 107924. https://doi.org/10.1016/j.buildenv.2021.107924

Liu, Z., Lu, Y. & Peh, L.C. (2019). A review and scientometric analysis of global Building Information Modeling (BIM) research in the architecture, engineering and construction (AEC) industry. Buildings, 9(10), 210. https://doi.org/10.3390/buildings9100210

Locatelli, M., Seghezzi, E. & Di Giuda, G.M. (2021). Exploring BIM and NLP applications: A scientometric approach. In S. El Baradei, A. Abodonya, A. Singh & S. Yazdani (eds), Proceedings of International Structural Engineering and Construction, 8(1), CON-12-1–CON-12-6. ISEC Press. https://doi.org/10.14455/ISEC.2021.8(1).CON-12

Locatelli, M., Seghezzi, E., Pellegrini, L., Tagliabue, L.C. & Di Giuda, G.M. (2021). Exploring Natural Language Processing in construction and integration with Building Information Modeling: A scientometric analysis. Buildings, 11(12), 583.

Lu, K., Deng, X., Jiang, X., Cheng, B. & Tam, V.W.Y. (2023). A review on life cycle cost analysis of buildings based on building information modeling. Journal of Civil Engineering and Management, 29(3), 268–288. https://doi.org/10.3846/jcem.2023.18473

Michán, L. & Muñoz-Velasco, I. (2013). Cienciometría para ciencias médicas: definiciones, aplicaciones y perspectivas. Investigación en Educación Médica, 2(6), 100–106. https://doi.org/10.1016/S2007-5057(13)72694-2

Ouzzani, M., Hammady, H., Fedorowicz, Z. & Elmagarmid, A. (2016). Rayyan: A web and mobile app for systematic reviews. Systematic Reviews, 5, 210.

Ozturk, G.B. (2020). Interoperability in building information modeling for AECO/FM industry. Automation in Construction, 113, 103122. https://doi.org/10.1016/j.autcon.2020.103122

Ozturk, G.B. (2021). Digital twin research in the AECO-FM industry. Journal of Building Engineering, 40, 102730. https://doi.org/10.1016/j.jobe.2021.102730

Öztürk, G.B. (2020). Trends in interoperability in building information modeling (BIM) research: A scientometric analysis of authors and articles. ITU A|Z, 17(3), 169–183. https://doi.org/10.5505/itujfa.2020.79026

Pereira, V., Santos, J., Leite, F. & Escórcio, P. (2021). Using BIM to improve building energy efficiency: A scientometric and systematic review. Energy and Buildings, 250, 111292. https://doi.org/10.1016/j.enbuild.2021.111292

Saieg, P., Sotelino, E.D., Nascimento, D. & Caiado, R.G.G. (2018). Interactions of building information modeling, lean, and sustainability in

the architecture, engineering, and construction industry: A systematic review. Journal of Cleaner Production, 174, 788–806.
Santos, R., Costa, A.A. & Grilo, A. (2017). Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015. Automation in Construction, 80, 118–136. https://doi.org/10.1016/j.autcon.2017.03.005
Slafer, G.A. (2009). ¿Cómo escribir un artículo científico? Revista de Investigación en Educación, 6, 124–132.
Tam, V.W.Y., Zhou, Y., Illankoon, C. & Le, K.N. (2022). A critical review on BIM and LCA integration using the ISO 14040 framework. Building and Environment, 213, 108865. https://doi.org/10.1016/j.buildenv.2022.108865
Tanko, B.L., Zakka, W.P. & Heng, W.N. (2022). BIM in the Malaysian construction industry: A scientometric review and case study. Engineering, Construction and Architectural Management. https://doi.org/10.1108/ECAM-04-2021-0324

Teng, Y., Xu, J., Pan, W. & Zhang, Y. (2022). A systematic review of the integration of building information modeling into life cycle assessment. Building and Environment, 221, 109260. https://doi.org/10.1016/j.buildenv.2022.109260
Universidad Nacional Autónoma de México (UNAM) (2023). Ingeniería Civil – Plan de estudios 2023. Disponible en: https://www.ingenieria.unam.mx/programas_academicos/licenciatura/civil_plan2023.php
Wang, T., Ali, A.S. & Au-Yong, C.P. (2022). Exploring a body of knowledge for promoting the building information model for facility management. Ain Shams Engineering Journal, 13, 101717. https://doi.org/10.1016/j.asej.2022.101717
Wen, Q., Ren, Z., Lu, H. & Wu, J. (2021). The progress and trend of BIM research: A bibliometrics-based visualization analysis. Automation in Construction, 124, 103558. https://doi.org/10.1016/j.autcon.2021.103558
Wen, Q.-J., Ren, Z.-J., Lu, H. & Wu, J.-F. (2021). The progress and trend of BIM research: A bibliometrics-based visualization analysis. Automation in Construction, 124, 103558. https://doi.org/10.1016/j.autcon.2021.103558
Xu, Y. & González, C.M.G. (2020). La vinculación entre la educación superior y el desarrollo económico de China. Revista Conjeturas Sociológicas, 149–171.
Zhao, X. (2017). A scientometric review of global BIM research: Analysis and visualization. Automation in Construction, 80, 37–47. https://doi.org/10.1016/j.autcon.2017.04.002
Zhao, Y. & Taib, N. (2022). Cloud-based Building Information Modelling (Cloud-BIM): Systematic literature review and bibliometric-qualitative analysis. Automation in Construction, 142, 104468. https://doi.org/10.1016/j.autcon.2022.104468
Zhong, B., Wu, H., Li, H., Sepasgozar, S., Luo, H. & He, L. (2019). A scientometric analysis and critical review of construction related ontology research. Automation in Construction, 101, 17–31. https://doi.org/10.1016/j.autcon.2018.12.013
Zou, Y., Kiviniemi, A. & Jones, S.W. (2017). A review of risk management through BIM and BIM-related technologies. Safety Science, 97, 88–98. https://doi.org/10.1016/j.ssci.2015.12.027