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Review

Big Data, Data Science, and Artificial Intelligence for Project Management in the Architecture, Engineering, and Construction Industry: A Systematic Review

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Abstract: The high volume of information produced by project management and its quality have become a challenge for organizations. Due to this, emerging technologies such as big data, data science and artificial intelligence (ETs) have become an alternative in the project life cycle. This article aims to present a systematic review of the literature on the use of these technologies in the architecture, engineering, and construction industry. A methodology of collection, purification, evaluation, bibliometric, and categorical analysis was used. A total of 224 articles were found, which, using the PRISMA method, finally generated 57 articles. The categorical analysis focused on determining the technologies used, the most common methodologies, the most-discussed project management areas, and the contributions to the AEC industry. The review found that there is international leadership by China, the United States, and the United Kingdom. The type of research most used is quantitative. The areas of knowledge where ETs are most used are Cost, Quality, Time, and Scope. Finally, among the most outstanding contributions are as follows: prediction in the development of projects, the identification of critical factors, the detailed identification of risks, the optimization of planning, the automation of tasks, and the increase in efficiency; all of these to facilitate management decision making.

Keywords: artificial intelligence; architecture, engineering, and construction (AEC) industry; big data; data science; digital twins; Internet of Things; project management

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1. Introduction

The architecture, engineering, and construction (AEC) industry is one of the most dynamic economic sectors in the world. It is also an essential source of economic growth in the wake of the COVID-19 pandemic. The sector's market value will reach $14.7 trillion by 2030. In turn, this sector is associated with at least 13% of the world's Gross Domestic Product, and employs more than 200 million people worldwide [1]. In this context, project management in the AEC sector presents multiple challenges associated with its complexity. The design and construction phases are consecutive, articulated, and dependent. Buildings undergo constant design modifications that are informed by the executors, as well as bidirectional processes, until the product is delivered to satisfaction after the project [2,3].

Among the most important international problems in the management of AEC projects are the following [2,4–7]:

- Planning problems: lack of detailed resource assessment, incorrect estimates and focus problems in defining activities.
- Communication failures: communication problems between contractors, stakeholders, suppliers, customers, and project teams.
- Inaccurate scope management: incorporation of unauthorized changes and lack of clarity in including crucial aspects of the project.

- Cost control problems: over-budget projects, poor initial estimates, and price inflation, among others.
- Risk-management difficulties: delivery delays, quality issues, safety issues, and lack of money, among others.
- Quality problems: Lack of clear standards, defects, complaints and low satisfaction. Non-compliance with established metrics.

Many of these challenges in project management, mainly when a large volume of data has been used, have been addressed in recent years with new models, concepts, and technology. Several authors have proposed taking advantage of new technologies such as big data, data science, and artificial intelligence in the management of AEC projects [8–12].

The first aspect to be considered in this article is big data, understood as the use of large data sets to analyze patterns, trends, and behaviors [13]. This concept highlights using new architectures and software designs to make the process more efficient [14–17]. There are many models that can be used to process big data. One of these proposes the following as a route: data collection, problem identification and understanding, data preprocessing, data mining, evaluation, modeling, results, and the generation of useful knowledge [18,19]. In the construction sector, big data have been used to make predictive models to optimize costing, automate activity planning, establish knowledge bases from historical data, and improve quality indicator measurements, among others [20–25].

A second technology that has become quite popular is data science, understood as the discipline responsible for extracting valuable information from large data sets. In data science, using statistics and automatic algorithms is a crucial aspect [26–28]. Data science goals include identifying trends and segmentations in a market, characterizing and profiling stake-holders, and facilitating risk management, among others [29]. Some of the possible methodologies to carry out data science are: KDD (Knowledge Discovery in Databases), SEMMA (Sample, Explore, Modify, Model, and Access), ASUM DM, TDPS, and CRISP-DM (Cross-Industry Standard Process for Data Mining). Each has its own characteristics, advantages, and disadvantages [30].

In the construction sector, data science has been used mainly for the following: improving the project life cycle integrated with BIM; quality improvement in design and construction processes; project decision making; parametric cost estimation; and project scope tracking and risk management [31–37]. In this sense, there is a clear difference between big data and data science. The former focuses on the volume, variety and velocity of big data, and the latter provides the methods and techniques with which to analyze them and extract useful information.

Another important technology for this review is artificial intelligence, which emerges as a strategy based on algorithms that allow machines (from a broad understanding of that definition) to carry out processes, make decisions, and emulate the human brain [38–41]. Essentially, these are algorithms with the ability to learn and train themselves. Some of the most important applications of artificial intelligence is predictive analysis in processes, pattern estimation, and the design of solutions adapted to contexts and constraints.

Among the most popular artificial intelligence technologies are: deep learning, the support vector machine (SVM), the K-nearest Neighbors Algorithm, Random Forest, Decision Tree, and the Naive Bayes Classifier. Genetic algorithms, neural networks, fuzzy logic, machine learning, and computer vision are also examples of artificial intelligence, and are popular in the AEC industry [38,42,43]. In the construction sector, their use has been highlighted for the automatic planning of activities, optimization in resource management, effective information communication and collaborative platforms, and improvement in cost management, among others [44–47].

This review specifically contributes to generate an updated state of the art on the use of emerging technologies (big data, data science, and artificial intelligence) in the life cycle of projects, mainly in the architecture, engineering, and construction (AEC) industry. It seeks to be a guide, to approach the subject so that academics and companies in the productive sector can recognize and integrate these technologies. Methodologically, it proposes the use of the systematic literature review proposed by [48] and the PRISMA method. The manuscript is organized as follows: Methodology (Section 2), Bibliometric Analysis (Section 3), Categorical Analysis (Section 4), Discussion and Conclusions (Section 5), Limitations and Future Research Directions (Section 6), and Practical Implications of the Review (Section 7).

2. Materials and Methods

This article seeks to be a contribution to academic literature, identifying through a systematic review of the literature, based on the methodology proposed by [48], the use, appropriation, and results of the incorporation of big data, data science, and artificial intelligence in the construction sector. This contribution will make it easier for those interested in the topic to understand the existing dynamics at the global level. This methodology proposes a phase of six steps, summarized as follows: (1) formulation of research questions to guide the systematic review of the literature; (2) definition of search terms and equations, as well as the selection of the most relevant databases for the area of knowledge; (3) formulation of inclusion and exclusion criteria, which allows us to define further and refine the bibliographic search; (4) bibliometric analysis of the articles resulting from the review; (5) evaluation of the scientific quality of publications obtained using pre-defined quality criteria, including in the final category the analysis of only those that passed this evaluation; and (6) conducting categorical analysis focused on the use, appropriation, and challenges of using the technologies in the construction sector. The development of these steps is presented below:

Step 1: research question (RQ): The following questions have been considered, all based on the records obtained:

RQ_1: What are the technologies most used in the articles found in the review?

RQ_2: What are the most-used methodological routes?

RQ_3: What are the most-used specific fields of construction project management (from the areas of knowledge of the PMI)?

RQ_4: What are the main recommendations regarding implementing emerging technologies in the construction sector?

Step 2: Databases and search terms: The bibliographic review is conducted in the Scopus bibliographic index. The equation used was:

("project management" OR "project administration") AND ("big data" OR "data science" OR "Artificial Intelligence") AND ("buildings" OR "civil engineering" OR architecture OR "facility management" OR AEC).

After the results of the five databases were unified, the data were purified (elimination of duplicates, adjustment of authors with multiple names, and adjustment of affiliations with different names, among others). This was carried out using VantagePoint 12 software.

Step 3. Formulation of inclusion and exclusion criteria: The initial inclusion and exclusion criteria that were proposed in the review were as follows: (1) review period: 2015–2022; (2) the types of documents that were included in the review are articles in journals, conference papers, and systematic literature reviews. With this corpus of knowledge, the bibliometric analysis of this article was conducted.

Step 4. Bibliometric analysis of articles: In this step, bibliometric analysis is performed with specific indicators to determine trends related to the field of knowledge and the evolution that this has experienced. The Scopus data analysis tool is used, after the purification of duplicate records, to obtain: (1) an analysis of the number of publications per year, (2) an analysis according to the type of publication, (3) an analysis of the main scenarios (journals) where the records are found, and (4) an analysis of publications by country.

Step 5. Analysis of the scientific quality of publications: To further clarify the systematic review of the proposed research questions, the following criteria are established for the screening process: (1) the documents must be in full text, (2) the documents must be associated with the construction sector, (3) the documents must have as the technology used those of interest in the article, and (4) the documents should not be just theoretical analyses. These exclusion criteria were applied, prompting 80 articles to proceed with a quality evaluation. To verify the quality of the articles, the methodology proposed by [48] was applied and adapted by [49,50], using 11 criteria.

These criteria focus on:

- General category: clarity of the objective (1) and selection of the appropriate method for the research question (2).
- Sample selection category: Sufficient information to generate conclusions (3) and clarity in the context of the research (4).
- Method category: The selected method is indicated (5), the method is argued (6) and variables affecting the process are considered (7).
- Data analysis category: The data are adequately analyzed (8), the results are clearly presented (9), and the reliability and validity of the research are reported (10).
- Conclusions category: The research question is answered based on empirical evidence (11).

Each criterion was evaluated on three scales: 1, not defined; 2, 0.5, present but not defined. Each criterion was evaluated on three scales: (1) 0, not defined; (2) 0.5, present but not clear; and (3) 1, present. To be included in the systematic review, the articles had to obtain a minimum score of 5.5 for the 11 criteria, that is, at least half of the maximum possible score. After this quality control, 57 articles remained eligible for inclusion in this review.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA diagram) guidelines were used [51,52]. PRISMA is shown in Figure 1.

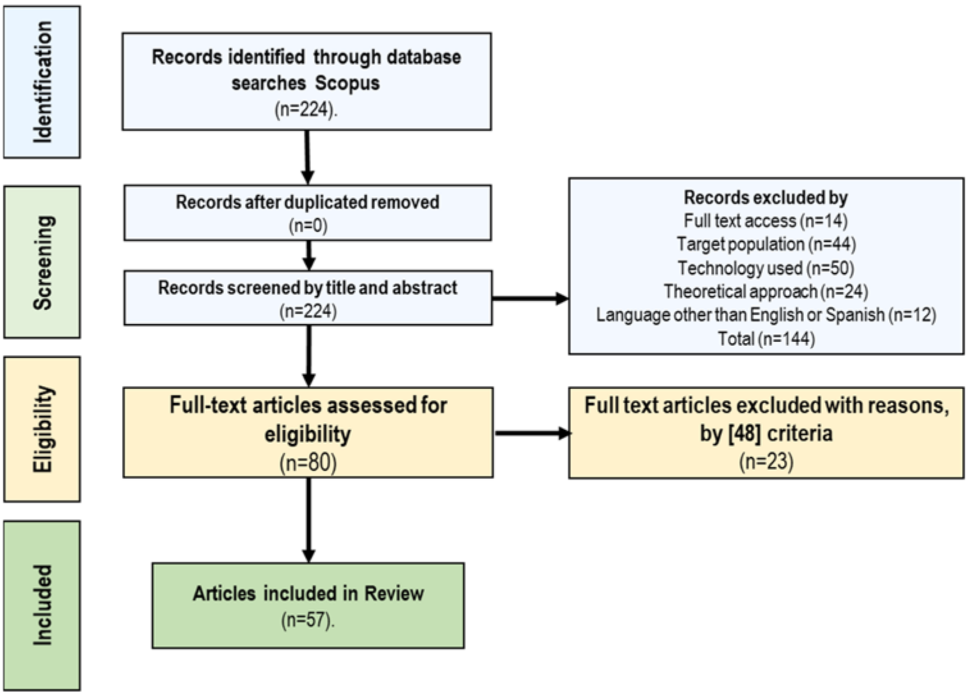

Figure 1. PRISMA diagram (Preferred Reporting Items for Systematic reviews and Meta-Analyses) of process used for the review [48].

However, Table 1 lists an identifier (ID) for each of the articles in the review, the title, the bibliographic reference, the year of publication, the number of citations, the type of document, the methodology used, and the main technology applied.

Table 1. Complete list of articles included in this review.

ID	Title	Year	Type	Method	Technology
1	Artificial intelligence in the AEC industry: Scientometric analysis and visualization of research activities [36].	2020	Review	Literature Review	Artificial Intelligence
2	Bridging BIM and building: From a literature review to an integrated conceptual framework [9].	2015	Article	Quantitative	Big Data/Data Science
3	Integrating semantic NLP and logic reasoning into a unified system for fully-automated code checking [12].	2017	Article	Quantitative	Artificial Intelligence /Big Data
4	An effective approach for software project effort and duration estimation with machine learning algorithms [10].	2018	Article	Quantitative	Artificial Intelligence/Data Science
5	Construction with digital twin information systems [11].	2020	Article	Quantitative	Artificial Intelligence/Big Data/Data Science
6	Deep learning in the construction industry: A review of present status and future innovations [53].	2020	Article	Quantitative	Artificial Intelligence /Big Data
7	Optimizing decisions in advanced manufacturing of prefabricated products: Theorizing supply chain configurations in off-site construction [8].	2017	Article	Quantitative	Data Science
8	Comparing AHP and CBA as decision methods to resolve the choosing problem in detailed design [54].	2015	Article	Mixed	Data Science
9	Research trend of the application of information technologies in construction and demolition waste management [37].	2020	Review	Literature Review	Artificial Intelligence /Big Data
10	A framework for data-driven informatization of the construction company [55].	2019	Article	Qualitative	Big Data/Data Science
11	Performance-based control of variability and tolerance in off-site manufacture and assembly: optimization of penalty on poor production quality [56].	2020	Article	Qualitative	Artificial Intelligence/Data Science
12	Semantic enrichment of building and city information models: A ten-year review [57].	2021	Article	Mixed	Data Science
13	Investigating profitability performance of construction projects using big data: A project analytics approach [58].	2019	Article	Quantitative	Big Data
14	Evaluating industrial modularization strategies: Local vs. overseas [59].	2020	Article	Quantitative	Data Science
15	Predicting the Volatility of Highway Construction Cost Index Using Long Short-Term Memory [60].	2020	Article	Quantitative	Artificial Intelligence
16	Knowledge-based system for resolving design clashes in building information models [61].	2020	Article	Qualitative	Artificial Intelligence
17	Overview of Applications of the Sensor Technologies for Construction Machinery [62].	2020	Article	Quantitative	Big Data/Data Science
18	Building a rough sets-based prediction model for classifying large-scale construction projects based on sustainable success index [4].	2018	Article	Quantitative	Artificial Intelligence/Data Science
19	Estimating construction duration of diaphragm wall using firefly-tuned least squares support vector machine [63].	2018	Article	Quantitative	Artificial Intelligence
20	Options for and Challenges of Employing Digital Twins in Construction Management [64].	2022	Article	Qualitative	Artificial Intelligence/Big Data/Data Science
21	Research Status and Challenges of Data-Driven Construction Project Management in the Big Data Context [47].	2021	Review	Literature Review	Artificial Intelligence/Big Data/Data Science
22	Automated Monitoring of Construction Sites of Electric Power Substations Using Deep Learning [65].	2021	Article	Mixed	Artificial Intelligence/Data Science
23	Transformer machine learning language model for auto-alignment of long-term and short-term plans in construction [66].	2021	Article	Qualitative	Artificial Intelligence
24	The effectiveness of project management construction with data mining and blockchain consensus [67].	2021	Article	Mixed	Artificial Intelligence/Big Data/Data Science
25	Symbiotic organisms search-optimized deep learning technique for mapping construction cash flow considering complexity of project [68].	2020	Article	Quantitative	Artificial Intelligence/Data Science
26	An anatomy of waste generation flows in construction projects using passive bigger data [69].	2020	Article	Quantitative	Big Data
27	Development and Application of an Industry Foundation Classes-Based Metro Protection Information Model [70].	2018	Article	Mixed	Artificial Intelligence/Big Data/Data Science
28	Artificial Intelligence and Robotics for Prefabricated and Modular Construction: A Systematic Literature Review [71].	2022	Review	Literature Review	Artificial Intelligence
29	Implementing Remote-Sensing Methodologies for Construction Research: An Unoccupied Airborne System Perspective [72].	2022	Review	Literature Review	Data Science
30	An intelligent fuzzy-based hybrid metaheuristic algorithm for analysis the strength, energy and cost optimization of building material in construction management [73].	2021	Article	Quantitative	Artificial Intelligence
31	A genetic algorithm tool for conceptual structural design with cost and embodied carbon optimization [74].	2022	Article	Quantitative	Artificial Intelligence
32	Construction Project Cost Management and Control System Based on Big Data [75].	2022	Article	Mixed	Big Data
33	Investigation of intelligent safety management information system for nuclear power construction projects [76].	2020	Conference Paper	Qualitative	Artificial Intelligence/Big Data/Data Science

Table 1. *Cont.*

ID	Title	Year	Type	Method	Technology
34	Construction of Intelligent Building Design System Based on BIM and AI [77].	2020	Conference Paper	Qualitative	Artificial Intelligence/Big Data
35	Artificial Intelligence In Construction Asset Management: A Review Of Present Status, Challenges And Future Opportunities [78].	2022	Article	Quantitative	Artificial Intelligence
36	Developing an Integrative Data Intelligence Model for Construction Cost Estimation [79].	2022	Article	Qualitative	Artificial Intelligence
37	Intelligent Risk Management in Construction Projects: Systematic Literature Review [80].	2022	Article	Quantitative	Artificial Intelligence
38	Automated progress monitoring of construction projects using Machine learning and image processing approach [81].	2022	Article	Qualitative	Artificial Intelligence/Data Science
39	Acceptance Of Contemporary Technologies For Cost Management Of Construction Projects [82].	2022	Article	Quantitative	Artificial Intelligence/Data Science
40	The Influence Mechanism of BIM on Green Building Engineering Project Management under the Background of Big Data [83].	2022	Article	Mixed	Data Science
41	Exploring the Application of BIM Technology in the Whole Process of Construction Cost Management with Computational Intelligence [84].	2022	Review	Literature Review	Data Science
42	Development of Economic Evaluation System for Building Project Based on Computer Technology [85].	2022	Article	Qualitative	Artificial Intelligence
43	Artificial Intelligence Technology Based on Deep Learning in Building Construction Management System Modeling [86].	2022	Article	Quantitative	Artificial Intelligence/Data Science
44	Complex works project management enhanced by Digital Technologies [87].	2022	Conference Paper	Qualitative	Artificial Intelligence/Big Data/Data Sciencei
45	Research on detailed design of prefabricated building based on BIM and big data [88].	2021	Conference Paper	Literature Review	Big Data/Data Science
46	Research on Key Construction Technology of Building Engineering under the Background of Big Data [89].	2021	Conference Paper	Mixed	Big Data/Data Science
47	Query Answering System for Building Information Modeling Using BERT NN Algorithm and NLG [90].	2021	Conference Paper	Qualitative	Artificial Intelligence/Data Science
48	Research on digital collaborative management model of engineering projects based on BIM and IPD [91].	2021	Conference Paper	Mixed	Inteligencia artifical/Big Data
49	A Method for Image Big Data Utilization: Automated Progress Monitoring Based on Image Data for Large Construction Site [92].	2021	Conference Paper	Mixed	Big Data/Data Science
50	Design of a process mining alignment method for building big data analytics capabilities [93].	2021	Conference Paper	Mixed	Big Data/Data Science
51	Big Data as a Project Risk Management Tool [94].	2018	Conference Paper	Mixed	Big Data
52	Data lakes in business intelligence: Reporting from the trenches [95]	2018	Conference Paper	Qualitative	Big Data
53	The Applied Exploration of Big Data Technology in Prefabricated Construction Project Management [96]	2017	Conference Paper	Qualitative	Big Data/Data Science
54	Digital transformation of the construction design based on the building information modeling and internet of things [97]	2021	Conference Paper	Qualitative	Big Data/Data Science
55	Challenges of big data in the age of building information modeling: A high-level conceptual pipeline [98]	2015	Conference Paper	Literature Review	Big Data
56	Digital Technology in Architecture, Engineering, and Construction (AEC) Industry: Research Trends and Practical Status toward Construction 4.0 [22]	2022	Conference Paper	Quantitative	Artificial Intelligence/Big Data/Data Science
57	Collaborative Construction Industry Integrated Management Service System Framework Based on Big Data [99]	2019	Conference Paper	Qualitative	Big Data/Data Science

Step 6—Category Analysis: This analysis identified elements that allowed us to answer the research questions. In the first instance (related to question 1), the technologies most used in the sector, aimed at project management, were identified from each registry. In addition to those defined as initial categories: big data, data science, and artificial intelligence, the Internet of Things (IoT) was also included as an emerging category. Associated with question 1, the different methodological routes of each registry were reviewed, considering qualitative, quantitative, mixed, and a systematic review of the literature. In this case, the specific research designs used were also reviewed.

The review of the specific fields of project management is presented in question three, analyzed from the areas of knowledge of the PMI [100]. Based on the review of the conclusions and recommendations of the articles, the guidelines, suggestions, and future work proposed in the research associated with the selected records are analyzed for question 4. These elements answer the central question: How have emerging technologies (big data, data science, and artificial intelligence) been implemented in civil works and construction project management?

3. Bibliometric Analysis

This section presents the bibliometric analysis associated with the literature review. The first analysis presented is the number of publications per year. It is limited to the range from 2015 to 2022, the time window used in the review. An incremental trend has been observed recently, with a positive slope until 2022, as seen in Figure 2.

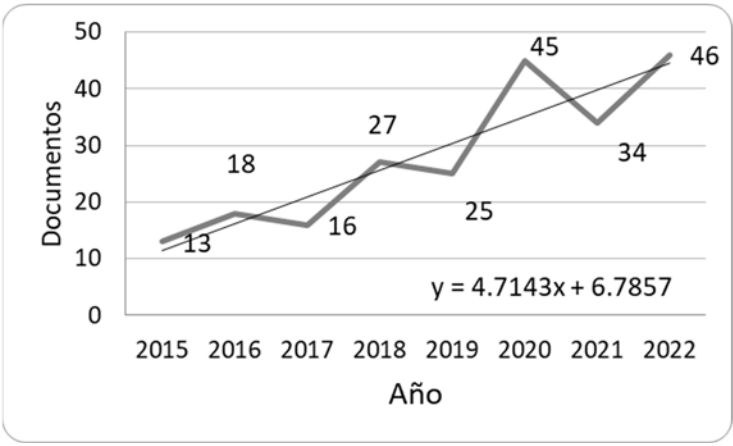

Figure 2. Documents by year.

Regarding the type of records found in the review: conference papers (55%), scientific articles in indexed journals (31%), conference reviews (8%), and reviews (6%). Regarding the dispersion of the scientific literature, the list of publications (journals and conferences) with the highest number of records is presented in Table 2.

Table 2. List of sources (conferences and magazines) with the largest number of records.

Type	Title	ISSN/ISBN	Quartile (Scopus)	H-Index	Number of Articles
Conference	ACM International Conference Proceeding Series	N/A	N/A	137	11
Conference	Procedia Computer Science	18770509	N/A	109	11
Journal	Advances in Intelligent Systems and Computing	21945365	Q4	58	8
Journal	Automation in Construction	9265805	Q1	157	7
Conference	Communications in Computer and Information Science	18650937	Q4	62	6
Conference	Journal of Physics: Conference Series	17426588	Q4	91	5

The dynamics of publication by country is led by China. This country accounts for 34% of the records found in the review. In second place is the United States with 10%, followed by other countries such as the United Kingdom, Australia, and Hong Kong. Figure 3 shows these results in greater detail.

On the other hand, as for the co-authorship network, it is presented with the support of the VOSviewer 1.6.20 software. A central node is observed in China, which maintains a collaborative network with Australia, Hong Kong, and Singapore. Iran, Iraq, Saudi Arabia, and Malaysia also share co-authorships. In Europe, there is interaction between the United Kingdom, Norway, and Israel. It is important to note that there is no strong co-authorship network, and there is still a need to increase exchange and cooperation in the field, as seen in Figure 4. Finally, the relationship between the main keywords of the articles is presented in Figure 5. The occurrences stand out as follows: project management (192), artificial intelligence (92), architectural design (58), big data (67), and information management (57).

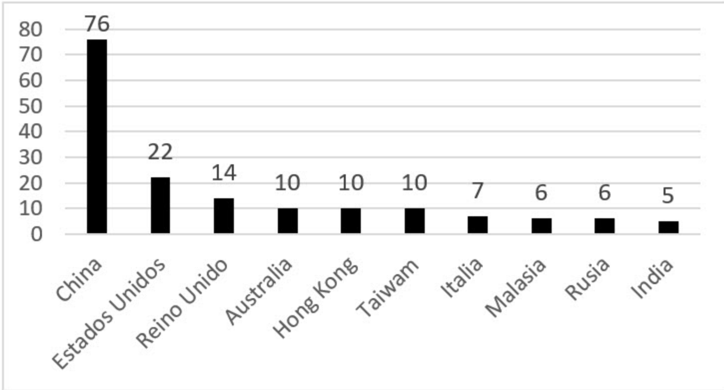

Figure 3. Documents by country/territory.

Figure 4. VOSviewer mapping of co-authorships by country.

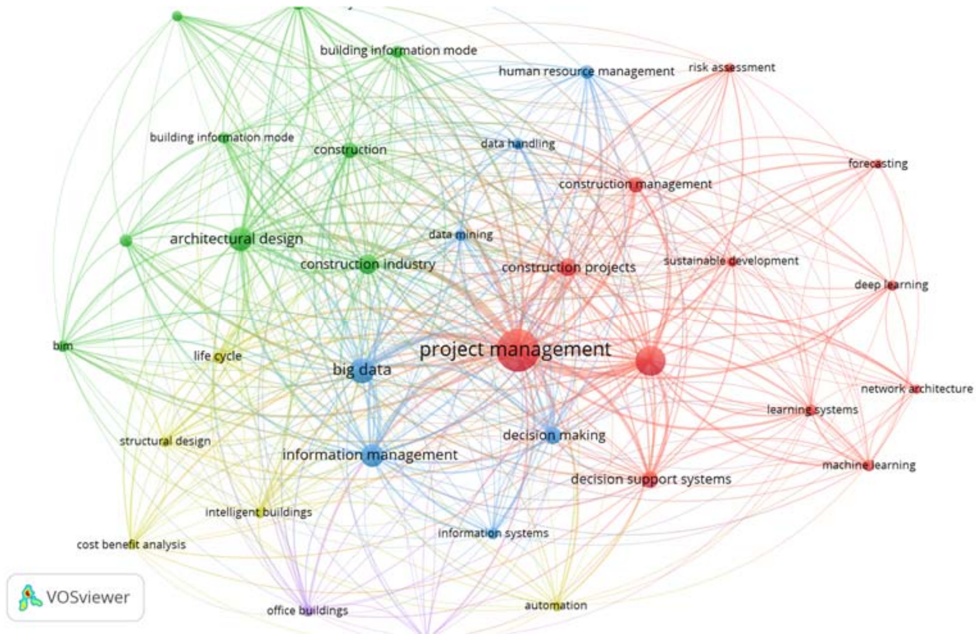

Figure 5. VOSviewer co-occurrence mapping by keyword.

4. Categorical Analysis

This section presents the findings that allow us to answer research questions. This analysis was conducted following step 6, presented in the methodology. The item nomenclature presented in Tables 3–5 is related to that established in the ID of Table 1.

4.1. Question 1—What Are the Technologies Most Used in the Articles Found in the Review?

Because the records do not present a specific type of technology, but on the contrary, several combine two or more of these, it was decided to classify them into the categories shown in Table 3.

Table 3. Summary of articles by technology used.

Technology Type	Number of Articles	Articles
Artificial Intelligence	12	1, 15, 16, 19, 23, 28, 30, 31, 35, 36, 37, 42.
Big Data/Data Science	9	2, 10, 17, 45, 46, 49, 50, 54, 57.
Artificial Intelligence/Data Science	9	4, 11, 18, 22, 25, 38, 39, 43, 47.
Artificial Intelligence/Big Data/Data Science	8	5, 20, 21, 24, 27, 33, 44, 56.
Data Science	7	7, 8, 12, 14, 29, 40, 41.
Big Data	7	13, 26, 32, 51, 52, 53, 55.
Artificial Intelligence/Big Data	5	3, 6, 9, 34, 48.

The first technology to consider in terms of the number of publications is artificial intelligence, which is considered a paradigm based on algorithms that allow machines (from a broad understanding of that definition) to conduct processes, make decisions, and generally emulate the human brain [39,41]. Different artificial intelligence approaches and applications include natural language processing, computer vision, expert systems, robotics, and voice recognition. These systems can conduct tasks such as the analysis of construction designs [36,71,74], optimization in the use of materials [60,71], schedule and critical route management [63,66,78], risk analysis, and the economic evaluations of projects [36,61,80], among others. Regarding specific techniques, we found that artificial neural networks (BPNN) were used for pattern analysis, and least squares support vector machine (LS-SVM) was incorporated for time prediction and schedule planning. Also, the integration of Artificial Intelligence and Robotics (AIR) for large-scale modularization processes comes up in the review, as well as Monte Carlo analysis and system dynamics for risk identification and management. Machine learning for time management is also used in several publications.

One of the benefits of artificial intelligence in project management is the ability to process large amounts of data and extract valuable information. The algorithms can analyze historical patterns, identify trends, and predict project performance. This helps project managers to make informed decisions and adjust the planning and allocation of resources in real time [60,61,101].

The second concept to consider is big data, understood as the use of large data sets to analyze patterns, trends, and behaviors [13,15]. Big data are usually associated, according to some mnemotechnical resources, with the 7 Vs, that is, volume (amount of data), velocity (interconnections and speed of creation, storage, and processing of data), variety (different formats, types, and sources), veracity (associated with the uncertainty of the data, in other words, the degree of reliability), viability (efficient use that can be given to data), visualization (how data are presented) and value (data that transform into information that becomes knowledge). The development of big data requires distributed storage and processing systems, data analysis algorithms, and data mining techniques, among others [16].

Big data have become essential for developing the BIM (building information model) methodology, since it allows real-time and synchronized information for decision making and the possibility of generating spaces for interoperability between systems [55]. Cost control, resource optimization, projection based on synchronized information, and contract management in the AEC projects are also processes that can be optimized using big data [75]. A method for data mining and resource management in project management, based on big data, is proposed as a strategy to optimize organizational processes [93].

On the other hand, the concept of data science is part of the technologies found. This strategy is the discipline responsible for extracting valuable information from large data sets. Data science combines statistical, mathematical, programming, and domain elements to extract valuable information and generate knowledge from the data [26]. The data science process involves several phases, including the collection and cleaning of data, the exploration and visualization of data, the modeling and statistical analysis, and the interpretation and communication of the results. Data science uses advanced tools and techniques, such as machine learning, data mining, data visualization, and artificial intelligence, to extract relevant information from data sets. This technology is also widely used for the management of sustainable projects, with a high ecological and environmentally friendly component, particularly when developed in conjunction with the BIM strategy [54,72,84]. The articles mainly include the use of SEMMA (Sample, Explore, Modify, Model, and Assess) methodology to facilitate decision making in projects, the use of Blockchain to support data immutability, the integration of BIM methodology with city information models to strengthen project integration, and the implementation of the AHP (analytical hierarchy process) method to support decision-making methods.

This technology's goals include identifying trends and segmentations in a market, characterizing and profiling stakeholders, and facilitating risk management, among others [29]. In the records selected for this review, there are experiences where using data science makes it possible to optimize purchasing decisions, strategic preferences, cost management, and financial modeling [56,84]. Data science is also considered for constructive analysis (optimization) and sustainable (green) construction articulated with BIM [54,83].

Other technologies that emerge from the review are the Internet of Things (IoT) and wireless sensor networks (WSNs), defined as the interconnection of monitoring devices, allowing data to be collected and shared. This collection is carried out through electronic devices with sensors whose information is transmitted wirelessly, automatedly, efficiently, and without direct human intervention [102–104]. In the architecture, engineering, and construction (AEC) industry, using sensors to monitor variables that allow recording the progress of projects and the status of the workers in them is a topic of widespread interest [62]. Another important topic is the use of wireless sensors for the monitoring of emissions, the carbon footprint, and in general and the environmental impact that the construction sector has on its environment, as well as the determination of strategies for modeling and mitigating this impact [76,78,82].

Finally, several of the articles present the concept of the digital twin. This is a virtual representation of a real-world system. It is created by collecting process data and allows an accurate replica to be generated to facilitate understanding, analysis and simulation and decision making about the system or object [11,47,64,78,80].

4.2. Question 2—What Are the Most-Used Methodological Routes, and with What Distribution?

In the field of emerging technologies (big data, data science and artificial intelligence) in architecture, engineering, and construction (AEC) industry project management, the main methodological route used is quantitative (22 records). The qualitative and mixed routes have 15 records each, and there are 7 records in the literature review method. See Table 4.

More than 80% of the publications related to this review report the design and validation of specific models in project management, both in field implementation and in the development of case studies or validation by experts.

Table 4. Summary of studies by method used.

Research Method	Number of Articles	Articles
Quantitative	22	2, 3, 4, 5, 6, 7, 13, 14, 15, 17, 18,19, 25, 26, 30, 31, 35, 37, 39, 43, 56.
Qualitative	15	10, 11, 16, 20, 23, 33, 34, 36, 38, 42, 44, 47, 52, 54, 57
Mixed	12	8, 12, 22, 24, 27, 32, 40, 46, 48, 49, 50, 51.
Literature review	8	1, 9, 21, 28, 29,41, 44, 55.

4.3. Question 3—What Are the Most-Used Specific Fields of Construction Project Management (from the Areas of Knowledge of the PMI)?

According to the PMI framework [100], the following areas of knowledge are available: integration, scope, time, costs, quality, risks, acquisitions, communications, human resources, and stakeholders. For this question, it is essential to clarify that the different registers do not usually contain a single area of knowledge of the PMI. This information is presented in Table 5.

Project cost management (22 records) mainly features the use of emerging technologies to perform budget forecasting and projection [77,79,85], as well as the early detection of anomalies in financial and operational data [8,53,58]. Data science is also used to simulate different scenarios and assess the impact of decisions on the final project budget [64,68,74]. Generating real-time information on the financial status of the project is also a contribution of data science [55,59,84]. This facilitates rapid decision making and cost adjustment if necessary.

About the analysis of quality management (19 articles) highlights the use of big data and data science as a strategy to collect data related to project quality to identify trends and areas for improvement. This involves the prediction, through artificial intelligence, of potential problems through analyzing historical and current data [4,10,12,77]. This allows taking preventive measures to avoid errors. This is also associated with the detection of anomalies in real time for the generation of alerts. Another aspect is that data science facilitates the management and analysis of information quality, ensuring that it is more accurate and useful for the project [53,61,64,73].

Regarding time management (17 records), the main aspects are automatic schedule planning from historical data of similar projects, including activity sequencing and activity duration [10,60,62,64]. The prediction of deviations or changes can be achieved using big data, allowing adjustments to be made in real time to avoid backlogs. Artificial intelligence enables efficient resource management and task allocation according to availability [69,82,85,86]. Also, the possibility of simulating different scenarios to evaluate the impact on the schedule of different decisions can be achieved with the use of emerging technologies [58,59].

Regarding scope management (15 articles), one of the main contributions evidenced is the use of data science to analyze historical data and thus facilitate the definition of objectives and project planning in general [9,11,57,59]. There are also examples of the use of artificial intelligence, which, using predictive models, allows deviations in the scope of the project to be anticipated, facilitating decision making. Other articles cite how artificial intelligence is used to adapt scope management strategies to the specific needs of each project [80,81,87,88].

In risk management (13 articles), the most common use is predictive analysis based on large volumes of data, which makes it possible to project potential risks. This strategy is recurrently used to avoid anticipated potential problems. Another application presented is the optimization of risk mitigation strategies based on data collected in projects [53,55,61]. There are some articles that propose the customization of risk strategies, based on artificial intelligence, so that the identification and planning of risks is based on the context, objectives, and constraints of each project [70,76,87].

A very important area that is also developed in the articles is the integration (coordination) of projects. The predictive performance analysis conducted using the combination of artificial intelligence and big data, which allows preventive measures to be taken, is highlighted. [54,71,78] The use of these technologies to integrate data from multiple sources and facilitate project and team management is also evidenced. Finally, the use of artificial intelligence as a way to simulate and review coordination scenarios and thus evaluate their impact on the project emerged [88,89,92,93].

In procurement management, the most recurrent example of the use of these technologies is the use of artificial intelligence to automate processes, from quotation management to supplier selection and purchasing. Authoring is also currently supported by emerging technologies [8,62,74,83]. Stakeholders, communications, and human resources are less involved, focusing on process optimization in these areas, as well as the best practices for presenting results to stakeholders [9,55,92].

Table 5. Summary of PMI project management knowledge areas used.

Project Management Knowledge Area	Number of Articles	Articles
Cost	22	1, 6, 7, 10, 11, 13, 14, 15, 18, 20, 21, 22, 25, 30, 31, 32, 34, 36, 39, 41, 42, 55
Quality	19	3, 4, 5, 6, 9, 11, 16, 17, 18, 20, 22, 29, 30, 33, 34, 41, 47, 53, 54.
Time	17	4, 13, 14, 15, 17, 19, 20, 22, 23, 26, 27, 28, 32, 38, 39, 43, 57.
Scope	15	2, 5, 12, 14, 28, 29, 32, 35, 37, 38, 40, 43, 44, 53, 55
Risk	13	1, 2, 6, 10, 16, 20, 25, 27, 33, 37, 42, 51, 57.
Integration	10	8, 35, 43, 45, 46, 48, 49, 50, 52, 54.
Procurement	6	7, 9, 17, 21, 31, 40.
Stakeholder	4	2, 18, 24, 55.
Communications	2	10, 24
Human resource	1	1

4.4. Question 4—What Are the Main Recommendations Regarding Implementing Emerging Technologies in the Construction Sector (AEC)?

These recommendations are segmented into each of the three technologies; however, it is important to indicate that several results overlap and enhance each other.

Regarding Big Data, they offer important contributions to the sector. The following are highlighted [62,69,76,85]:

- Collection, processing, storage, and analysis of large volumes of data generated in the industry, providing project managers with fundamental elements to make informed decisions. The records highlight the use of historical records, real-time data, sensor information, and stakeholder comments.
- Improved risk management, based on a wide range of data, allows risks to be identified, managed, and mitigated. This tool makes it possible to facilitate decision making regarding risks and the reduction in their negative impacts.
- Big data allow you to generate predictive analysis, pattern detection, trend identification, and correlation analysis to predict future events and optimize performance.
- Promotion of quality and customer satisfaction based on analyzing feedback from those interested in the project. The research highlights the analysis of surveys, contributions on social networks, and other channels. This contributes to customer satisfaction and improves the reputation of the project.
- Big data provide tools and platforms to share information, track progress, and facilitate communication and collaboration between project team members.

Regarding data science, this concept articulately contributes to big data in the following aspects [54,56,83,84]:

- It facilitates decision making by allowing the collection, analysis, and visualization of large amounts of data related to the project.
- Optimizing resource planning and allocation: through analyzing historical data and using optimization algorithms, data science can help project managers optimize the planning and allocation of resources.
- Improved productivity and efficiency: By using data science techniques, project managers can identify areas for improvement and optimization in the workflow. By analyzing performance data, such as task duration, resource usage, and bottlenecks, inefficiencies can be identified and addressed, leading to greater productivity and efficiency in project execution.
- Scope management and change control: Data science can help in project scope management and changing control. By analyzing data related to changes in scope, requests for changes, and these changes' impact on the project, managers can assess the risks and benefits of the proposed changes and make informed decisions about their approval or rejection.

Finally, Regarding artificial intelligence (the technology most cited in the review records), the following elements are highlighted [10,56,63,65]:

- Optimization in project planning and scheduling, using artificial intelligence algorithms from different sources.
- Identifying the most critical tasks and possibly allocating resources using artificial intelligence algorithms.
- Early detection of problems that can be converted into risks through data analysis and incorporating predictive algorithms.
- Improved decision making, allowing the identification of project patterns and trends. It is an excellent support for project managers to select routes based on detailed information.
- Automation in developing repetitive tasks to improve efficiency and reduce human errors. This is associated with the execution of more appropriate strategic planning, and it saves time and effort.
- Communication between team members, providing tools and platforms for sharing information, managing tasks, and encouraging effective communication. This also appears to be a trend towards developing project groups in different locations.

5. Discussion and Conclusions

In the architecture, engineering, and construction (AEC) industry, there are multiple and significant challenges in project management, both in the design and construction phases. The review shows that in recent years, the use of big data, data science, and artificial intelligence has demonstrated its value and has significantly impacted the efficiency and effectiveness of project management in this sector.

The results are contrasted with what was shown by previous reviews, such as references [36,37,84], showing that there is a growing trend of research on the subject. This review provides the classification of the articles found by PMI knowledge areas (Project Management Institute 2017), finding that the greatest interest of the academic community is in cost management [53,58,64,74,79], quality management [12,73,77], time management [57,60,62,82], and, finally, scope management [11,81,87]. There is a knowledge gap in the use of emerging technologies (big data, data science, and artificial intelligence) in the areas of stakeholder management, communications, and human resources, at least in the construction and civil works sector.

Big data provide a way to collect, process, and analyze the data generated in construction projects, thus constituting a very important source of information for decision making. By analyzing structured and unstructured data, such as historical records, sensor reports, real-time data, and client feedback, patterns, trends, and correlations can be identified that provide a comprehensive understanding of project status and performance. These results are presented in a manner consistent with those presented by several authors, including [89,90,93]. Another aspect to consider is that big data require a significant amount of care in the handling of information, which is primarily associated with cybersecurity. There are potential risks of the loss of information, theft of sensitive data, or possible improper modifications to the data.

On the other hand, data science also provides predictive analysis strategies and pattern detection to predict future project events. With this information, project managers in the construction sector can proactively take preventive or corrective measures, minimizing negative impacts on the project. In addition, resource planning and allocation are optimized by analyzing historical data and considering factors such as resource capacities, costs, and restrictions. Optimization processes emerge as a key outcome of data science's contribution to AEC industry project management, consistent with [54,56,59]. This improves operational efficiency, reduces unnecessary costs, and allows for a more effective allocation of available resources.

Also, artificial intelligence (AI) has played a fundamental role in project management in the construction sector. The results of this review show the frequent use of this technology, as seen in [12,53,60]. Using AI algorithms, the automation of routine and repetitive tasks has been achieved, saving time and resources. In addition, AI improves decision making by processing large volumes of data and generating valuable information. AI has also improved collaboration and communication between project team members by providing tools and platforms for sharing information, tracking progress, and encouraging effective communication, even if team members are in different geographical locations [61,66,91]. As a disadvantage, it is possible to highlight the technical complexity of implementing this technology, the initial costs and maintenance for the organizations, the integration with existing systems in the organization, organizational resistance, and excessive dependence on the technology.

Finally, in the architecture, engineering, and construction (AEC) industry, benefits include data-based decision making, pro-active risk identification and mitigation, resource planning and allocation optimization, and greater collaboration and communication within the project team. These technologies have demonstrated their ability to improve the construction sector's efficiency, productivity, and quality. One of the most critical challenges is the integration of these technologies into existing processes. Properly managing data privacy and security and training professionals are vital areas that must be addressed to maximize benefits and overcome limitations. In conclusion, using big data, data science, and artificial intelligence transforms how projects are managed in the construction sector. These technologies give project managers a more comprehensive and more accurate view of projects, improving decision making, operational efficiency, and customer satisfaction.

6. Specific Contributions to the Literature

This systematic literature review develops a topic of recent interest in the academic community, which is the use of emerging technologies (big data, data science, and artificial intelligence) in project management, particularly in the construction and civil works sector. Although there are antecedent reviews that contribute to the subject, this article focuses on determining the main contributions of the academic literature to project management from the different areas framed in its life cycle, taking as references the ten areas of the PMI and the use of emerging technologies in each of these. This contribution has also made it possible to classify the articles by type of technology (individual or combined), as well as the most common research routes used in the research published in Scopus in the last 7 years.

7. Limitations and Future Research Directions

In terms of limitations, by inspecting only articles indexed in Scopus between 2015 and 2022, it is possible that relevant references on the use of emerging technologies in project management have been omitted. It is also noted as a limitation of this article that it is necessary to delve deeper into sectors other than construction and civil works to obtain a more complete view of the use of big data, data science and artificial intelligence in project optimization. These sectors include finance, banking, healthcare, and transportation.

Regarding knowledge gaps, it is possible to highlight the following: There is a lack of further research into the use of technologies to dynamize projects, especially in project monitoring and control. Another important gap is the analysis of risks, mainly concerning their quantitative identification. Decision-making systems and BIM methodology are not clearly integrated in the literature reviewed. There are also few studies that generate complete models of the use of technologies in the sector that go beyond a pilot test or case study. It is a great opportunity for the sector to conduct more research on the use of emerging technologies in stakeholder management, communications, and human resources. In terms of the latter, the authors consider that there is a lack of development and that it is of enormous relevance.

For future research, it is recommended to thoroughly review emerging technologies (big data, data science, and artificial intelligence) within the project life cycle, mainly in those aspects that allow optimizing project management and organizational decision making. Readers interested in the topic are encouraged to research and build models on the use of these TEs in the monitoring, control and closure phases. The use of TE for historical management and facilitating lessons learned is not as widespread. It is also recommended to those interested not to limit the field of research only to the incorporation of technology in processes, but to review very carefully the development contexts, the ethical and social implications of the new strategies, and the potential risks that these technologies have.

8. Practical Implications of the Review

The present research allows the practical observation that the implementation of emerging technologies (big data, data science and artificial intelligence) in project management is increasingly being carried out in the fields of interest of the research. It can also be observed that there are additional key concepts associated with the above, such as digital twins and the Internet of Things, which can enhance the effects of project optimization.

The incorporation of these technologies does not focus on an exclusively technological issue, but requires the members of the organizations to have deeper competencies and skills. Understanding the concepts of digital transformation, Industry 4.0, interconnected processes, and decentralized structures, among others, is fundamental for the constant processes of training of managers and project team members of organizations.

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