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applied sciences

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Developing Standard BIM Execution Plans for Complex Construction Projects

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Abstract: This study addresses the critical need for standardizing building information modeling (BIM) execution plans (BEPs) in the architecture, engineering, construction, and operations (AECO) sector. Through the analysis of 36 BEP documents from international organizations, we have identified crucial components and put forth a comprehensive framework with the objective of improving digital transformation and collaboration in intricate construction projects. This study utilizes scientometric analysis to chart the development of BEP standards and incorporates empirical data from industry surveys to verify the suggested framework. The results of our research emphasize the advantages of using standardized building execution plans (BEPs) to decrease inefficiencies and enhance project outcomes. This makes a substantial contribution to the field of building information modeling (BIM) implementation.

Keywords: BIM execution plan; BIM framework; standardization of BIM execution plan; BIM procedures; BIM in construction projects

Citation: Abdelalim, A.M.; Shawky, K.; Alnaser, A.A.; Shibeika, A.; Sherif, A. Developing Standard BIM Execution Plans for Complex Construction Projects. *Appl. Sci.* **2024**, *14*, 6614. https://doi.org/10.3390/app14156614

Academic Editor: Syed Minhaj Saleem Kazmi

Received: 2 July 2024
Revised: 14 July 2024
Accepted: 15 July 2024
Published: 29 July 2024

1. Introduction

Building information modeling (BIM) has emerged as a fundamental element in the architecture, engineering, construction, and operations (AECO) sector, facilitating decision-making throughout all stages of a construction project [1,2]. Despite its widespread adoption, the standardization of BIM execution plans (BEPs) remains inconsistent, leading to inefficiencies and errors. Integrating BIM into existing project management frameworks often encounters resistance due to perceived complexity and reluctance to shift from traditional methods (Synek, 2018). Aligning BEPs with local standards and improving document management practices are crucial yet challenging tasks [3]. Coordination between various project teams is essential as managing and synchronizing vast amounts of project data in a BIM environment can significantly reduce errors and rework, though it remains challenging [4]. The empirical validation of BEPs through industry surveys highlights common inefficiencies and inconsistencies, reinforcing the necessity for a standardized approach adaptable to different project requirements while maintaining a cohesive methodology. Furthermore, recent studies have confirmed the necessity for standardized practices, especially in the initial stages of projects, to reduce inefficiencies and misalignments [5].

This study aims to address this gap by developing a standardized framework for BEPs tailored to complex construction projects. By analyzing 36 BEP documents and employing scientometric analysis, we aim to provide a globally applicable, adaptable framework that enhances collaboration and information sharing in BIM projects. To address this significant deficiency, the current study was undertaken to investigate the current state of implementation of business ethics and practices of BIM execution plan (BEP) in large-scale construction projects. This study conducted an extensive survey of 87 professionals in the industry to evaluate the perceived significance of various sections of building energy performance (BEPs), the incorporation of practices within project lifecycles, and the degree of familiarity and satisfaction with existing building information modeling (BIM) standards. The survey was aimed at professionals from various fields in the construction industry, guaranteeing a wide and comprehensive viewpoint [6,7].

The results unveiled a significant degree of agreement regarding the fundamental essence of BEPs, with a particular emphasis on the significance of management and project objectives. This was accompanied by an acknowledgment of the need to incorporate BEPs into project cycles at an earlier stage to optimize their efficacy. Furthermore, the study emphasized the need for substantial enhancements in aligning BEPs with local standards, improving document management, and promoting collaborative practices.

These observations emphasize the need for a standardized and adaptable strategy for BIM execution planning, which can effectively tackle the distinct challenges encountered in large-scale construction projects [8].

Implementing standardized best execution practices (BEPs) has the potential to significantly improve the clarity, efficiency, and effectiveness of project management in the AECO industry. Through the establishment of standardized protocols and procedures, projects can effectively circumvent the challenges of miscommunication and delays, resulting in improved outcomes and decreased costs.

Furthermore, the process of standardization can help to streamline the incorporation of modern technologies and methodologies, thereby improving the capabilities of building information modeling (BIM) [9].

This paper adds to the ongoing discussion on enhancing BIM implementation in large-scale construction by presenting empirical evidence on the current practices and difficulties in BEP utilization. Also, it suggests making iterative revisions and improvements to BEP frameworks to promote more efficient integration of BIM in the construction sector. The objective is to establish a base that not only fulfills the current operational requirements of large-scale projects but also allows for future advancements in construction technology.

1.1. Research Objective

The main objective of this study is to improve digital transformation in the AECO sector by developing a standardized framework for BEPs that can enhance collaboration and information sharing in BIM project

1.2. Novelty and Significance

The AECO industry has experienced significant progress through the incorporation of building information modeling (BIM) technologies. Nevertheless, even though the use of BIM has become widespread, there is still a lack of uniformity and cohesion in the standardization of BIM execution plans (BEPs) within the industry. This study focuses on an important and overlooked aspect of BIM implementation creating standardized BEPs specifically designed for complex construction projects. The subsequent points outline the distinctive contributions and innovative aspects of this research.

1.2.1. Innovative Framework for BEP Standardization

This study introduces a comprehensive and adaptable framework for BEP standardization, which is a significant advancement over existing models. This represents a significant improvement compared to current models. Our framework incorporates best practices from 36 BEP documents obtained from various international organizations, in contrast to previous studies that typically concentrate on individual aspects of BEPs or regional standards. This comprehensive approach guarantees that the suggested framework can be used worldwide, while still being adaptable to local regulations and specific project needs.

1.2.2. Scientometric Analysis of BEP Literature

A key novel aspect of this research is the use of scientometric analysis to examine the evolution and intellectual landscape of BEP research between 2020 and 2024. This method provides a quantitative assessment of the most influential works, key research themes, and prominent authors in the field, offering a data-driven foundation for the proposed framework. The integration of scientometric analysis into BEP standardization is a pioneering approach that enhances the credibility and relevance of the study's findings.

1.2.3. Empirical Validation through Industry Survey

To ensure practical relevance, this study incorporates an extensive survey of 87 industry professionals from various sectors within the construction industry. This empirical validation is crucial, as it grounds the theoretical framework in real-world experiences and challenges. The survey results highlight common inefficiencies and inconsistencies in current BEP practices, reinforcing the necessity for a standardized approach. This direct engagement with industry stakeholders is a distinctive feature that sets this research apart from previous work.

1.2.4. Addressing Regional and Project-Specific Challenges

While existing studies often overlook the specific challenges faced by large-scale construction projects in different regions, this research emphasizes the importance of aligning BEPs with local standards and practices.

By incorporating feedback from professionals operating in the MENA region, particularly Egypt and Saudi Arabia, this study addresses regional challenges and provides actionable insights for improving BEP adoption and effectiveness in these rapidly growing construction markets.

1.2.5. Integration of Emerging Technologies

The proposed framework not only standardizes traditional BEP elements but also incorporates provisions for integrating emerging technologies such as IoT, digital twins, and advanced data management systems. This forward-looking approach ensures that the framework remains relevant as the industry continues to evolve technologically.

2. Methodology

This research adopts a multi-faceted research design that incorporates scientometric analysis to scrutinize the current state of building information modeling (BIM) execution plans (BEPs) and their alignment with international standards. The methodological approach is detailed in Figure 1.

- Literature Review: An extensive literature review was undertaken, leveraging databases such as Web of Science and Scopus to identify pertinent publications from 2018 to 2024. The objective was to delineate prevailing trends and foundational concepts within BIM execution plans, ensuring a comprehensive and globally representative analysis.
- Document Analysis: The research critically examined 36 BEP documents chosen for their pivotal contributions to the domain. These documents, sourced from diverse global entities, were evaluated against international standards and guidelines. The analysis concentrated on content structure, practice methods, contractual stipulations, and project-specific characteristics.
- Scientometric Analysis: This component included citation and keyword analysis to delineate the intellectual terrain of BEP research. This analysis was instrumental in identifying key authors, institutions, and seminal publications, thereby shedding light on the evolution of the field and its key scholarly contributions.
  The use of scientometric analysis in this study is justified by its ability to evaluate the progress and development of research systematically and quantitatively within the field of BIM execution plans (BEPs). Scientometric analysis offers several key benefits:

(1) Mapping Research Trends: Scientometric analysis helps in identifying the most influential works, key research themes, and leading authors and institutions in the field of BEPs. This provides a comprehensive understanding of the intellectual landscape and highlights the evolution of research trends from 2020 to 2024.
(2) Objective Assessment: By analyzing citation data and keyword co-occurrences, scientometric analysis provides an objective assessment of the research impact and the relative importance of different studies. This helps in distinguishing foundational works from less influential ones, ensuring that the proposed framework is built on a robust foundation of significant contributions.
(3) Identifying Gaps: The analysis reveals gaps in the current literature and research, guiding the focus of this study toward underexplored areas. By identifying these gaps, this research can address specific deficiencies and contribute novel insights to the field.

- Factor Frequency Analysis: This analysis was employed to scrutinize the fundamental and ancillary elements of BEPs, identifying both commonalities and discrepancies across various documents. This approach facilitated a nuanced understanding of the standardization efforts within the field.
- Data Collection: Data collection was conducted from a variety of sources, including academic institutions, governmental agencies, national standard bodies, and industry professionals. This extensive gathering of data was crucial for capturing the varied methodologies and practices employed in BEP implementation.
- Comparative Analysis: An in-depth comparative analysis was performed, which synthesized the insights garnered and was discussed extensively in the results section of the study. The industry survey method was chosen for several reasons:
  - Practical Relevance: Surveys captured the practical experiences and challenges faced by industry professionals in implementing BEPs. This ensured that the proposed framework was grounded in real-world practices and addressed the actual needs of stakeholders.
  - Broad Perspective: By surveying 87 industry professionals from various fields within the construction industry, the study gathered a wide range of viewpoints. This diversity enhanced the generalizability of the findings and ensured that the framework is applicable across different contexts and project types.
- Empirical Validation Through Industry Survey:

The survey data provide a means to validate the proposed BEP framework. By comparing the theoretical insights gained from document analysis and scientometric analysis with empirical data, this study can refine and adjust the framework to better align with industry practices and expectations.

1. Enhancing Reliability and Applicability

Combining scientometric analysis with industry surveys enhances the reliability and applicability of the findings in several ways:

(1) **Robust Data Foundation:** Scientometric analysis offers a robust, data-driven foundation by highlighting influential studies and key themes. This ensures that the proposed framework is supported by the most relevant and impactful research in the field.
(2) **Empirical Validation:** Industry surveys provide empirical validation, ensuring that the theoretical framework is relevant and applicable. This dual approach bridges the gap between theory and practice, making the findings more reliable and actionable.
(3) **Comprehensive Understanding:** By integrating both quantitative and qualitative data, this study achieves a comprehensive understanding of BEPs. The scientometric analysis provided a macro-level view of research trends, while the surveys offered micro-level insights into practical challenges and needs.

(4) **Addressing Practical Challenges:** The empirical data from industry professionals highlight specific areas where BEPs currently fall short. This direct feedback informed the refinement of the framework, ensuring that it addressed real-world challenges and enhanced project outcomes.

- **Integration of Emerging Technologies:**

Provisions for integrating emerging technologies such as IoT, digital twins, and advanced data management systems should be incorporated into the proposed BEP framework. It should be ensured that the framework remains relevant as the industry evolves technologically.

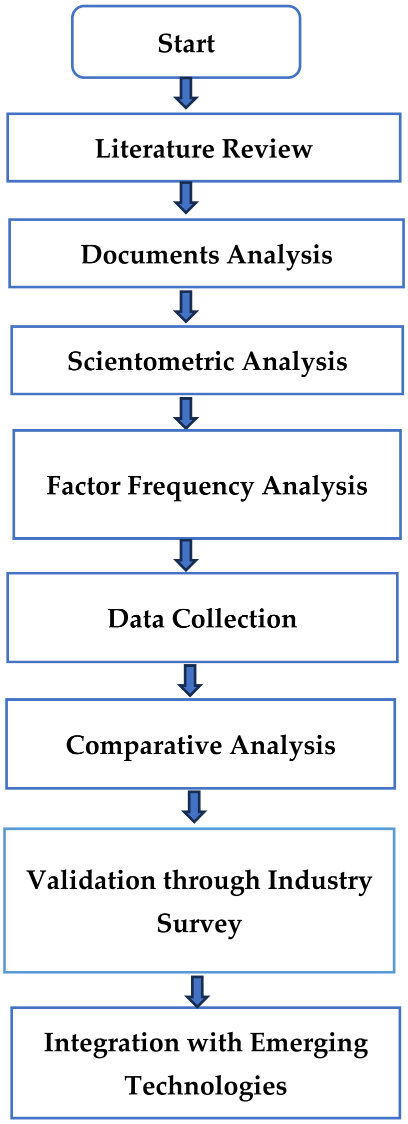

Figure 1. The methodological approach.

2.1. Literature Review

The adoption of building information modeling (BIM) in the construction industry has been increasingly recognized as a transformative force, particularly for large-scale construction projects. The literature on BIM emphasizes its potential to enhance transparency, efficiency, and collaboration across various stages of the construction lifecycle. However, a critical aspect that continues to challenge industry professionals is the standardization of BIM execution plans (BEPs), which are essential for managing the complexities inherent in mega construction projects [10].

Recent studies highlight that while BIM offers substantial benefits in terms of project management and operational efficiency, the lack of standardized BEPs can lead to significant barriers to implementation. The proposed BEP framework, derived from the comprehensive analysis of 36 globally recognized BEP documents, addresses these inconsistencies by integrating the most frequently occurring elements identified across diverse BEP guidelines. This framework includes detailed management structures, project goals, roles and responsibilities, technology infrastructure needs, and quality control processes, all of which are designed to be adaptable to various project requirements while maintaining a standardized approach [9].

A significant body of research has focused on the elements of BEPs. According to Antunes and Elliot [11], the effective implementation of BIM requires a clear understanding of project goals, roles, and responsibilities, as well as collaboration procedures and quality control measures. These components are essential to ensuring that BIM technologies are used effectively to support project outcomes.

The literature also discusses the impact of BIM on project coordination and information management. For instance, Galitskaya [4] points out that BIM facilitates improved coordination between different project teams, which is crucial in mega projects involving multiple stakeholders. The ability to manage and synchronize vast amounts of project data in a BIM environment can significantly reduce errors and rework, enhancing overall project quality. However, the integration of BIM into existing project management frameworks remains a challenge. I have attempted to address these challenges by proposing frameworks that align BIM execution planning with international standards like ISO 19650 [3]. These frameworks aim to standardize the processes involved in BIM execution planning, thus providing a clearer pathway for its adoption in the construction industry [12]. Despite the potential benefits of standardized BEP frameworks, [13] indicates that the actual adoption and implementation of these frameworks are not widespread. The barriers to adoption include a lack of understanding of the benefits of BIM, the perceived complexity of implementing new systems, and resistance to change from traditional project management approaches [14]. In conclusion, while BIM is poised to revolutionize the construction industry, the standardization of BEP remains a crucial step that requires more focused research and development [4]. The literature suggests that standardized BEP frameworks can facilitate better integration of BIM into construction projects, leading to improved project outcomes and efficiency. The ongoing evolution of BIM technologies and methodologies will continue to influence the development of new standards and practices in the field [15]. BEPs are often incorporated into the project contract to establish clear expectations and responsibilities, ensuring that all parties are aligned on BIM processes and deliverables. By defining roles, workflows, and data-exchange protocols, BEPs help to mitigate risks and enhance project outcomes [5].

Integrating risk management within BEPs involves identifying potential project risks, assessing their impact, and establishing mitigation strategies. This proactive approach enhances collaboration, minimizes uncertainties, and improves project outcomes. By addressing risks early, BEPs help ensure a project's efficiency and success [16].

Integrating advanced technologies such as digital twin and BLE (Bluetooth low energy) can significantly enhance resource positioning and management. Abdelalim et al. (2024) demonstrated the potential of agent-based modeling in optimizing construction resource allocation through real-time data integration, which can be crucial for improving project efficiency and decision-making processes. Incorporating these technologies into BEPs can provide more accurate and dynamic resource management, aligning with the goals of enhanced project outcomes and risk mitigation [17].

2.2. Document Analysis

The study entailed a meticulous analysis of 36 building information modeling (BIM) execution plans (BEPs), chosen for their significant contributions to the field. The documents were obtained from various international organizations, covering a diverse array of mandates, guidelines, and protocols. The analysis concentrated on various crucial facets:

Content Structure: The documents underwent analysis to determine their content structure, specifically examining how information was structured and presented within each BEP.

Practice Methods: The analysis examined the methods and practices suggested in the documents, evaluating their suitability and efficacy in real-life situations.

Data Collection: A comprehensive collection of data was obtained from academic institutions, government bodies, national standards agencies, and industry professionals. The comprehensive data collection was crucial for comprehending the varied approaches and practices in implementing BEP.

2.3. Scientometric Analysis

This study performs a comprehensive Scientometric analysis by utilizing the Web of Science and Scopus databases to investigate the development of scientific subjects and patterns within the field of building information modeling (BIM) execution plans (BEP) from 2020 to 2024. This era is distinguished by significant progress in business process engineering (BEP). The analysis employs citation and keyword analysis to chart the academic terrain, pinpointing prominent authors, institutions, and influential works that have influenced BIM standards and practices. The knowledge acquired from this analysis is crucial in guiding future strategies and initiatives to establish standardized BIM execution plans. The literature review of the study presents a comprehensive summary of the existing research and application of BEP content and structure in BIM projects. It emphasizes a significant lack of specialized literature on the factors that influence the progress of BEPs. The absence of standardized protocols for the development of BEPs is recognized as a notable hindrance, leading to inconsistent and inefficient project implementation [18].

2.3.1. Analysis of the Simultaneous Presence of the Most Important Keywords

Keyword co-occurrence analysis is a powerful method for visually representing the evolution and modifications of scientific topics over time. Figure 2 visually displays the author keywords that are frequently used in BIM execution plan studies, as recorded by the Web of Science between 2020 and 2024. The chosen time frame corresponds to the period with the most publications on BEP, amounting to 36 documents. The visualization depicts the frequency of occurrence of these keywords, providing insights into the dominant areas of research.

Figure 2 displays a vibrant network diagram created by VOS viewer, a tool used for constructing and visualizing bibliometric networks. The purpose of this analysis is to visually represent the occurrence and relationship between keywords in a specific dataset related to BIM research. The term "BIM" is prominently positioned, signifying its central importance in research, while other significant terms such as "framework", "construction", and "design" are grouped around it.

Figure 3, obtained using the VOS viewer tool, visually displays the main themes found in BIM execution plan research from 2020 to 2024, as recorded in the Scopus database. The complex network of keywords demonstrates the ever-changing nature of this discipline, emphasizing the close connection between terms such as 'architectural design', 'construction industry', and 'building information modeling', which frequently co-occur. The diagram, characterized by diverse color clusters, illustrates the extensive and interdisciplinary nature of BIM research. It is based on the examination of 68 documents, which highlight the specific areas of interest and scholarly focus within the academic community.

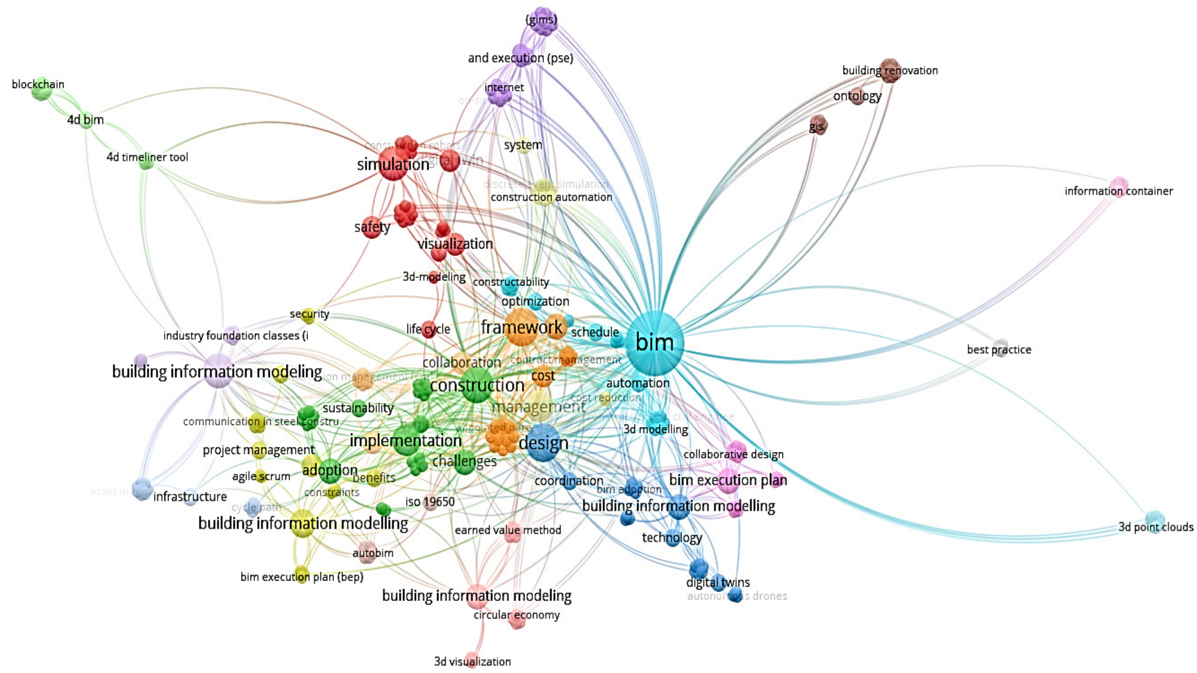

Figure 2. Web of Science searches. Co-occurrence of the top keywords.

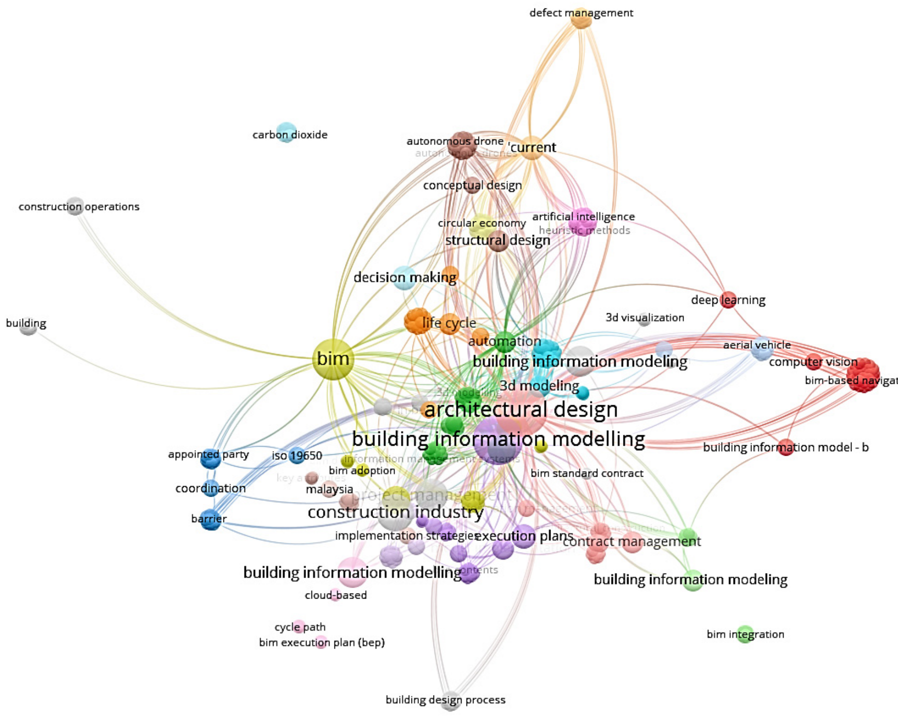

Figure 3. Scopus searches. Co-occurrence of the top keywords.

The list of the identified documents is in Table 1, totaling thirty-six (36), identified, compared, and analyzed. The findings highlight the crucial elements necessary for the development of BEPs. A thorough elucidation allows all parties involved to understand the project's objectives, process, allocated responsibilities, data prerequisites, and specifications for the final output. Hence, the business execution plan (BEP) framework can function as a roadmap for the progress and improvement of BEP. The study's findings offer a comprehensive range of parameters for researchers and practitioners to develop tools that improve the effectiveness of implementing BIM projects. Kindly refer to Appendices A and B.

Table 1. The list of identified documents.

1.	Post contract—award BIM execution plan (BEP)	19.	BIM Project Execution Plan Guide BIM Forum
2.	Australia and New Zealand guide to IOS 19650	20.	BIM execution plan to infrastructure superintendence of the federal university of Pernambuco—federal university in Brazil
3.	Template for BIM Execution Plan Christchurch City Council	21.	Guideline (BIM) for Transport and Main Roads Queensland
4.	Solar boat BIM method statement	22.	Hong Kong Housing Authority BIM standards and guidelines
5.	The New Zealand BIM handbook (BEP Template)	23.	BIM project execution planning guide 3
6.	O-west BIM execution plan	24.	Smithsonian facilities' BIM guidelines
7.	Uc San Diego—BIM guidelines 2019	25.	CIC BIM standards General 2021
8.	Guide 5 BIM project guide a Guide to Enabling BIM in Projects—Malaysia—2019	26.	Digital twin guidelines Columbia—chips
9.	BIM and ISO 19650 from a project management perspective	27.	Georgia tech BIM execution plan template
10.	State of Tennessee Office of the State Architect—2020	28.	Pre-appointment and Delivery Team's BEP Guidance-University of Cambridge
11.	BEP based on ISO 19650-1,2 Standards—Istanbul University	29.	(BIM) for Infrastructure Federal Highway Administration
12.	BIM Contract Conditions of Contract for Building Information Modeling The Hong Kong Institute of Surveyors	30.	NBIMS-US Project Committee and Public Review the National Institute of Building Sciences (NIBS)
13.	BIM Beyond Design guidebook (2020) ACRP research report.	31.	Kvmrt-BIM-execution-plan-template-intel build
14.	A Section Interpretation of Significance Values building execution plan (BEP)	32.	Multnomah County BIM execution plan template
15.	Journal of Construction Engineering, Management & Innovation.	33.	Ohio-state_BIM_pds_v2022
16.	Exchange information requirements for water care	34.	Massachusetts Institute of Technology
17.	Building Information Modeling for Transport and Main Roads A guide to enabling BIM on Road Infrastructure Projects.	35.	University of Nebraska Medical Center Project
18.	Western Michigan University	36.	University of Tennessee

Through the examination of thirty-six (36) BEPs, it was revealed that all of them exhibit a common theoretical framework.

The presentation of the content and the titles of the chapters exhibited dissimilarities. The building execution plan (BEP) outlines project information, project goals, BIM objectives, BIM use roles and responsibilities, BIM process design, BIM information exchange, collaboration procedures, model structure, quality control, technology infrastructure needs, and project deliverables [3,19].

Table 2 displays the frequency of sub-elements in the reviewed documents that have a percentage higher than 50%. The factor is determined by the equation provided:

$$Factor = \frac{\text{Number of element occurrence}}{\text{Total number of Documents (36)}} \tag{1}$$

Table 2. Frequency distribution of key topics in BIM execution plan literature.

BIM Project Execution Plan Overview	Project Goals and Objectives
Project information	BIM Team
Task information delivery plan (TIDP)	Project Phases/Milestones
Responsible Parties	Detailed Modeling Plan
Project deliverables	Document Management
BIM Uses	Roles and Responsibility
BIM Model and Level of Development	Information Management Risk Register
Collaboration procedures	Master information delivery plan
Common Data Environment "CDE"	Key project contacts
Software requirements	Measurement and coordination systems
Hardware	Modeling Information
Data Validation and Verification	Model Ownership of Elements
Review and Approval Processes	Health and safety
Audit and Continuous Improvement	Survey strategy
Volume Strategy	File Naming Conventions
Model Coordination Procedures	Federated Model Color Scheme
Version Control	Model structure
Models Coordination	Coordination Approach
Tolerance Strategy	Quality Management
(Methods and Procedure)	Compliance plan

Figure 4 displays the frequency of occurrence of the sub-element's topics in the reviewed documents. This identifies the topics with the highest percentage, which will be chosen as the main elements for the proposed BIM execution plan framework. Figure 4 displays the elements in the document comparison that have the highest percentage.

This table is a structured compilation of key topics frequently addressed in the literature about BIM execution plan (BEP) standardization. It categorizes 40 distinct aspects ranging from foundational elements like "BIM Project Execution Plan overview" to more specialized topics such as "federated model color scheme". This tabulation serves as a reference point for the distribution of focus areas within the body of BEP literature, highlighting the multifaceted nature of BIM implementation and management in construction projects. Figure 4 illustrates a bar chart detailing the frequency of occurrence for various sub-elements within the topics covered in the reviewed BIM execution plan documents. The chart presents a descending order of frequency, starting with the most commonly occurring sub-elements on the left. The percentages above each bar indicate the proportion of documents that mention each sub-element, providing a clear visual representation of which aspects within the BIM execution plans are given the most emphasis in the literature [2].

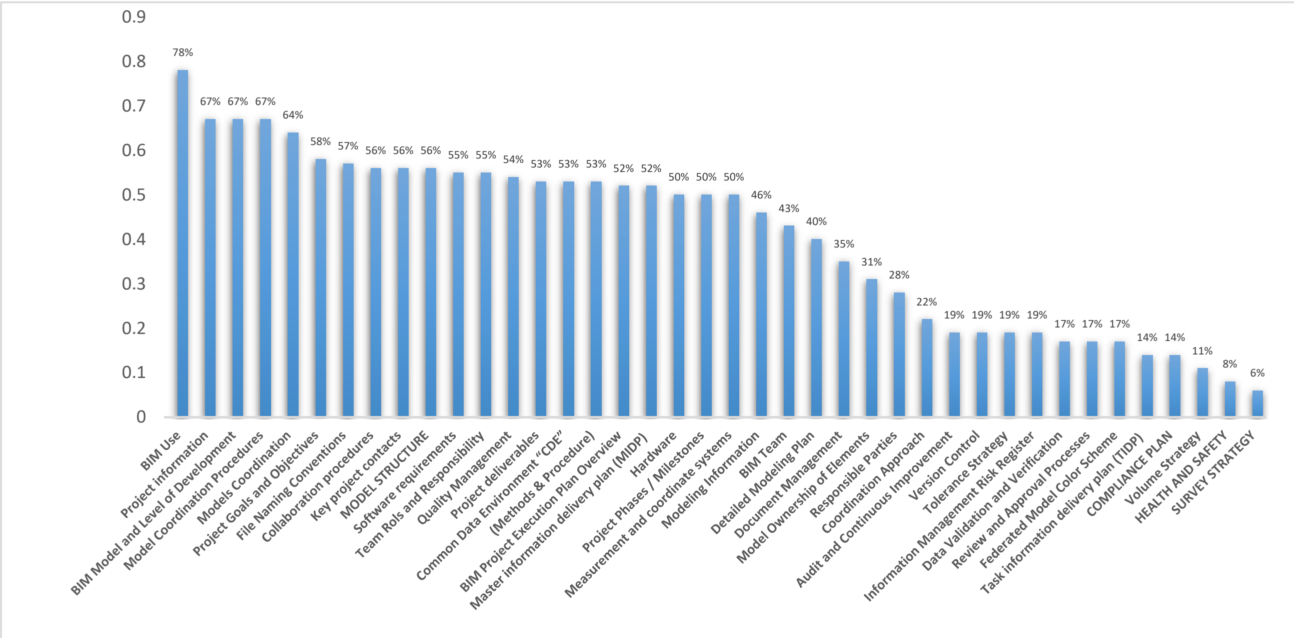

Figure 4. The percentage of occurrence of the sub-element's topics in the reviewed document.

2.3.2. Pareto Analysis

Pareto Analysis, a statistical technique in decision-making, is based on the Pareto Principle, which posits that 80% of the effects come from 20% of the causes for many events, as displayed in Table 3. This method is integral to identifying the most significant factors in a set of data, which, in the context of BIM execution plans, helps prioritize standardization efforts. By focusing on the few critical elements that cause the most significant impact, researchers and practitioners can streamline processes, optimize resource allocation, and drive substantial improvements in project outcomes [17].

Table 3. Pareto analysis of BEP sub-elements by frequency and impact.

	Sub-Elements	Number of Sub-Elements	Percentage	Percent 80%
1	BIM Use	29	7%	80%
2	BIM Model and Level of Development	26	14%	80%
3	Project information	25	20%	80%
4	Model Coordination Procedures	25	26%	80%
5	Project Goals and Objectives	23	32%	80%
6	Collaboration procedures	20	37%	80%
7	Roles and Responsibility	20	42%	80%
8	Common Data Environment	20	47%	80%
9	BIM Project Execution Plan Overview	20	51%	80%
10	Master information delivery plan	20	56%	80%
11	Model structure	19	61%	80%
12	Software requirements	19	66%	80%
13	Project deliverables	19	71%	80%
14	Project Phases/Milestones	19	75%	80%
15	File Naming Conventions	18	80%	80%
16	Measurement and coordination systems	18	84%	80%
17	Key project contacts	16	88%	80%
18	Quality Management	16	92%	80%

Table 3. *Cont.*

	Sub-Elements	Number of Sub-Elements	Percentage	Percent 80%
19	Methods and Procedure	16	96%	80%
20	Hardware	16	100%	80%
	Total	**404**		

The Pareto analysis displays the number and relative importance of sub-elements within BIM execution plans. The blue bars indicate the number of occurrences of each sub-element in the reviewed documents, while the orange line charts the cumulative percentage, highlighting that a small number of sub-elements account for a large percentage of the focus in BIM documentation. This analysis is a strategic tool for identifying critical areas for standardization and improvement. In the Pareto analysis figure, the sub-elements that surpass the 80% (BIM Use, BIM Model and Level of Development, Project information, Model Coordination, and Project Goals and Objective) threshold are of particular significance as they comprise the core content within the BIM execution plans. These critical elements are the main contributors to the substance of the documentation, representing most of what is deemed essential in literature. Identifying these allows for focused improvements in areas that will yield the most substantial impact on the standardization of BIM execution plans. The proposed framework, which requires validation through a literature review, is based on the results and analysis of the provided data in Table 4.

Table 4. The proposed framework.

Document Release History	
Definition	Abbreviation
	Other Definitions
BIM Project Execution Plan Overview	Executive Summary
	Vision Statement
	References
Project information	Project Description
	Project Stakeholders
	Project Scope of Work in details
	Project Masterplan
	Buildings Key plan
	Key Project Contacts
	Key Project BIM Management
Management	Project Phases/Milestones
	Key Roles and Responsibilities
	Project Deliverables
	Project Information Model Delivery Strategy
	Task information delivery plan (TIDP)
	Master information delivery plan (MIDP)
Project Goals/BIM Uses	Major BIM Uses
	BIM Workflow
	Level of Development (LOD)
	Level of Development Matrix

Table 4. *Cont.*

Document Release History	
Technical Requirements	Exchange Formats
	Software Needs/Scope
	Hardware Needs
	Data Security
	IT Upgrades
	Training
Quality Assurance/Quality Control (QA/QC) Plan.	Quality Assurance/Quality Control
	Design content Check
	Visual/Coordination Check
	Standards Check
	Interference Check
	Clash Criteria
	Model Size
	Model Warnings
	Information exchange
	Coordination Process
	Clash Matrix

2.4. Validation of the Proposed BEP Framework

Online questionnaires have gained popularity as a favored method in both the research community and the business world (Wu and Issa, 2013) [20]. The questionnaire's structure was designed to ensure data comparability, precise data recording, and streamlined data processing. Survey respondents were asked to rate their level of agreement on a Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questions focused on their knowledge and understanding of the status and issues related to BEPs.

2.5. Data Collection

This research employed an internet-based survey methodology to efficiently gather data from a diverse range of industry professionals. Online questionnaires have gained popularity in academic and commercial research because they can efficiently collect substantial amounts of data while maintaining the comparability and accuracy of the recorded responses. This study utilized a structured questionnaire to collect data on professionals' knowledge and comprehension of building information modeling (BIM) execution plans (BEPs) throughout different phases of large-scale construction projects. The survey consisted of questions assessed using a Likert-type scale, where participants indicated their level of agreement on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). This scale was selected to measure the levels of opinion regarding various aspects associated with BEPs [20]. Considerable attention was given to topics including the present state of BEP implementation, the perceived significance of various sections of the BEPs, and the level of satisfaction with existing BIM standards. The survey specifically focused on professionals from various disciplines within the construction industry, guaranteeing a wide-ranging and thorough collection of data points for analysis.

The survey data were utilized to enhance the BIM execution plan framework, incorporating practical applications and addressing challenges acknowledged by professionals. This approach not only connected the theoretical framework to practical reality but also emphasized areas for enhancing the standardization and integration of BEPs into project management workflows. This data collection method was crucial for comprehending the wide-ranging viewpoints within the industry and identifying essential areas for improvement in BIM execution planning.

3. Results

This section discusses the findings of the survey questionnaire, which was related to the implementation of building information modeling (BIM) execution plans (BEPs). The study runs descriptive statistics, demographic/respondent ratings, RII—relative importance index (RII) analysis as shown in Table 5, and reliability and confidence analysis to test the execution plan framework. The questionnaire extracted the opinions of the construction management personnel. The questionnaire was distributed in different project sizes in Egypt and Saudi Arabia, which are the two booming construction markets in the MENA region. The sample size is calculated as the following equation:

$$\text{SS (sample size)} = (z^2 * p\ (1 - p)/e^2 \quad (2)$$

where z = 1.64 at 95% confidence, p = 0.20, e = 0.80
SS (sample size) = $(1.64^2 \times 0.2(1 - 0.2))/0.08^2 = 68$

$$\text{SS new} = \text{SS}/(1 + (\text{SS} - 1)/\text{pop}) \text{ where, population} = 850{,}000 \quad (3)$$

Pop is the population considered for this research, as the number of engineers in the construction industry in Egypt and Saudi Arabia is 850,000, as determined by using the equation.

Table 6 summarizes the responses of construction management personnel from various projects in Egypt and Saudi Arabia, highlighting key demographics, experience, organizational categories, education levels, sector operations, company sizes, job levels, and familiarity with BIM Execution Plans (BEPs). The data provides insight into the respondents' backgrounds and perspectives on the use and importance of BEPs in mega-construction projects.

3.1. Descriptive Statistics

Table 7 shows the descriptive statistical summary that presents survey data on building information modeling (BIM) execution plans (BEPs) in Egyptian mega-construction projects (as an example of those in the MENA region). Respondents strongly agreed that all sections of the proposed BEP framework were essential for project success, with mean scores ranging from 4.45 to 4.68 on a 5-point scale. The "Management Section" and "Project Goals/BIM Uses Section" were the most important, scoring 4.67 each. A mean score of 4.68 indicates high agreement on the importance of standardizing BIM execution plans for mega construction projects in Egypt. BEP familiarity averaged 3.92 among respondents. BIM execution plans' integration into the project lifecycle at various stages had a lower mean score of 1.64, suggesting earlier integration may be rare. Due to a low mean of 1.30, respondents' BIM experience with mega construction projects varies.

Table 5. RII—Relative importance index analysis.

Proposed Framework for BIM Executive Plans (BEPs)	RII
How important do you think the Definition Section in the Proposed BEP Framework is?	68
How important do you think the BIM Project Execution Plan Overview Section in the Proposed BEP Framework is?	69.2
How important do you think the Project Information Section in the Proposed BEP Framework is?	93.2
How important do you think the Management Section in the Proposed BEP Framework is?	94
How important do you think the Project Goals/BIM Uses Section in the Proposed BEP Framework is?	89.2
How important do you think the Technical Requirements Section in the Proposed BEP Framework is?	87.6
How important do you think the Quality Assurance/Quality Control Plan Section in the Proposed BEP Framework is?	85.2

Table 6. Responses ratings based on respondents.

Categories	Frequency	Percent
Role in the construction industry		
Architect	31	35.6
Civil Engineer	30	34.5
Electrical Engineer	8	9.2
Mechanical Engineer	10	11.5
Other	8	9.2
Years of experience in the construction industry		
0–5 Years	10	11.5
5–10 Years	15	17.2
10–15 Years	31	35.6
15–20 Years	21	24.1
>20 Years	10	11.5
Category of the organization		
General engineering consultants	26	29.9
Project management consultants	3	3.4
General contractor	24	27.6
Specialized contractor	4	4.6
Owner	9	10.3
BIM Services	16	18.4
Other	5	5.7
Education		
Bachelor's degree	52	59.8
Master's degree	27	31.0
PhD	8	9.2
In which sector does your company operate?		
Public	11	12.6
Private	55	63.2
Both	21	24.1
In which sector does your company seek construction work?		
Public	7	8.0
Private	21	24.1
Both	58	66.7
Company size		
1–10	3	3.4
10–50	21	24.1
50–100	15	17.2
100–250	7	8.0
250–1000	15	17.2
>1000	26	29.9
Level of occupation		
Junior level	4	4.6
Senior level	22	25.3
Project Engineer	1	1.1
Projects Manager	13	14.9
BIM Coordinator	9	10.3

Table 6. *Cont.*

Categories	Frequency	Percent
Level of occupation		
BIM Manager	16	18.4
Top management	20	23.0
Other	2	2.3
Mega construction experience		
Residential	34	39.1
Commercial	10	11.5
Infrastructure	10	11.5
Mixed-use	11	12.6
Complex	2	2.3
Hospital	6	6.9
Educational Building	11	12.6
Other	3	3.4
Familiarity with BIM Execution Plans (BEPs)		
Not familiar at all	1	1.1
Familiar	6	6.9
Moderately familiar	17	19.5
Very familiar	38	43.7
Extremely familiar	25	28.7
At what stages of the project lifecycle do you integrate BIM Execution Plans?		
Design Stage	59	67.8
Tender Stage	6	6.9
Construction Stage	17	19.5
Operation Stage	4	4.6
Have you ever worked on a mega construction project that used BIM?		
Yes	61	70.1
No	26	29.9
How often do you refer to a BIM Execution Plan during the construction process?		
Never	3	3.4
Rarely	6	6.9
Occasionally	15	17.2
Frequently	37	42.5
Always	26	29.9
How important do you think standardization of BIM Execution Plans is for mega construction projects?		
Important	2	2.3
Moderately important	6	6.9
Very important	10	11.5
Extremely important	69	79.3
In your experience, does the outlined workflow address the unique challenges of BIM mega projects?		
No, not at all	2	2.3
Not Sure	4	4.6
Partially	20	23.0
Often	16	18.4
Completely	45	51.7

Table 7. Descriptive statistics.

Survey Questions	N	Mean	SD	Variance
How important do you think the Definition Section in the Proposed BEP Framework is?	87	4.45	0.818	0.669
How important do you think the BIM Project Execution Plan Overview Section in the Proposed BEP Framework is?	87	4.51	0.713	0.509
How important do you think the Project Information Section in the Proposed BEP Framework is?	87	4.55	0.695	0.483
How important do you think the Management Section in the Proposed BEP Framework is?	87	4.67	0.604	0.364
How important do you think the Project Goals/BIM Uses Section in the Proposed BEP Framework is?	87	4.67	0.604	0.364
How important do you think the Technical Requirements Section in the Proposed BEP Framework is?	87	4.63	0.649	0.421
How important do you think the Quality Assurance/Quality Control Plan Section in the Proposed BEP Framework is?	87	4.64	0.647	0.418
At what stages of the project lifecycle do you integrate BIM Execution Plans?	87	1.64	1.023	1.046
Have you ever worked on a mega construction project in Egypt that used BIM?	87	1.30	0.460	0.212
How familiar are you with BIM Execution Plans (BEPs)?	87	3.92	0.930	0.866
How important do you think standardization of BIM Execution Plans is for mega construction projects?	87	4.68	0.707	0.500
How often do you refer to a BIM Execution Plan during the construction process?	87	3.89	1.028	1.056
How satisfied are you with the proposed BIM Execution Plan workflow for implementation in BIM mega projects?	87	4.14	1.091	1.190
How well does the proposed BIM Execution Plan align with the current BIM standards and Workflow?	87	3.71	1.247	1.556
In which sector do you describe your company?	87	2.11	0.599	0.359
In which sector does your company seek construction work?	87	2.61	0.653	0.427
In your experience, does the outlined workflow address the unique challenges of BIM mega projects?	87	4.13	1.065	1.135
What is the category of your current organization?	87	3.40	2.037	4.150
What is the level of your current occupation?	87	4.60	2.099	4.406
What is your highest level of education?	87	1.49	0.663	0.439
What type of mega construction do you have experience in?	87	3.16	2.332	5.439
Which of the following best describes your role in the construction industry?	87	2.24	1.303	1.697
Years of experience in the construction sector?	87	3.07	1.159	1.344
Your Company Size	87	4.01	1.688	2.849
Valid N (list-wise)	87			

Demographically, the survey shows various construction industry experience, company sizes, and sectors. The mean current occupation and mega construction experience scores of 4.60 and 3.16 indicate a diverse group of professionals. This diversity is reflected in the average 3.07 years of construction experience. The proposed BEP workflow for BIM mega projects received a satisfactory mean score of 4.14, indicating a consensus on the BEP's importance. However, alignment with current BIM standards and workflow in Egypt has a lower mean score of 3.71, suggesting room for improvement or standardization and implementation gaps. These findings highlight the importance of BEPs in project execution and the need for standardization, early integration, and addressing Egypt's unique BIM mega project challenges.

3.2. Classification According to the Experience

Table 8's analysis of variance (ANOVA) provides nuanced insights into how construction experience influences the perceived importance of various sections within the building information modeling (BIM) execution plan (BEP) framework. The average scores for each section of the BEP show minor variations among various levels of experience, indicating that respondents agree on the significance of these sections regardless of their experience in the construction industry. Respondents with 0–5 years of experience rated the

"Management Section" and "Project Goals/BIM Uses Section" highest, with mean scores of 4.80. This indicates that early-career professionals recognize the significance of effective management and clear goal setting in BIM projects. The "Quality Assurance/Quality Control Plan" section received the highest average score of 4.93 from respondents with 5–10 years of experience. This suggests a strong emphasis on maintaining high quality at this stage of their careers.

Table 8. ANOVA with construction experience.

#	Section	Mean (0–5 Years)	Mean (5–10 Years)	Mean (10–15 Years)	Mean (15–20 Years)	Mean (>20 Years)	Mean (Total)	Std. Deviation	ANOVA F-Value	ANOVA Sig.
1	Definition Section	4.60	4.67	4.19	4.48	4.70	4.45	0.818	1.372	0.251
2	BIM Project Execution Plan Overview Section	4.60	4.73	4.32	4.48	4.70	4.51	0.713	1.138	0.344
3	Project Information Section	4.40	4.73	4.52	4.48	4.70	4.55	0.695	0.560	0.692
4	Management Section	4.80	4.73	4.55	4.62	4.90	4.67	0.604	0.866	0.488
5	Project Goals/BIM Uses Section	4.80	4.87	4.52	4.57	4.90	4.67	0.604	1.560	0.193
6	Technical Requirements Section	4.60	4.87	4.48	4.62	4.80	4.63	0.649	1.073	0.375
7	Quality Assurance/Quality Control Plan Section	4.70	4.93	4.55	4.48	4.80	4.64	0.647	1.470	0.219

An analysis of variance (ANOVA) was performed to investigate the statistical significance of differences in mean scores for the importance of different sections of the business execution plan (BEP) among respondents with varying levels of construction experience. The analyzed sections comprised the Definition Section, BIM Project Execution Plan Overview Section, Project Information Section, Management Section, Project Goals/BIM Uses Section, Technical Requirements Section, and Quality Assurance/Quality Control Plan Section.

The F-values and *p*-values obtained from the ANOVA tests were utilized to ascertain whether the experience levels significantly impacted the ratings of BEP sections. The p-value determined whether we rejected or did not reject the null hypothesis, which asserts that there is no variation in the means of the groups and that any observed variation is a result of random fluctuations [21–24].

Interpretation of Significance Values

- All tested sections yielded significant values (*p*-values) greater than 0.05, ranging from 0.189 to 0.692. This suggests that there are no statistically significant disparities in how individuals with varying experience levels perceive the significance of BEP sections.
- The absence of substantial disparities implies that the perceived significance of BEP sections is uniformly acknowledged among individuals with various levels of experience, indicating a widespread agreement among professionals irrespective of their tenure in the field.

3.3. Reliability

A popular statistical measure of scale or test item internal consistency or reliability is Cronbach's alpha. In the proposed building information modeling (BIM) execution plan specification (BEPS) framework, Cronbach's alpha values of 0.935 and 0.941 as shown in Table 9, with seven items, indicate excellent internal consistency [25].

Table 9. Cronbach alpha.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
0.935	0.941	7

3.4. Qualitative Feedback about BIM Execution Plans (BEPs)

This study also obtained feedback from the participants regarding BIM Execution Plans (BEPs) in Egypt. The respondents' findings regarding BEPs are presented in Table 10. The survey's qualitative feedback on the proposed BIM execution plan (BEP) framework for mega projects in Egypt provides valuable recommendations and highlights areas of improvement identified by industry professionals. The respondents identified various areas that needed improvement to better align with the Egyptian BIM standards. These areas include making management changes, clarifying document ownership, ensuring Cobie compliance, and enhancing collaboration and interoperability. These suggestions emphasize the necessity of a comprehensive and flexible business execution plan (BEP) that is customized to suit the unique requirements of various project categories. The inclusion of technology requirements, stakeholder roles and responsibilities, and data management and exchange protocols in the framework demonstrates a deeper comprehension of the intricate nature of BIM and the necessity for a thorough approach to project execution planning. Moreover, the feedback underscores the significance of streamlining the workflow to facilitate implementation and establish national standards for practices, thereby ensuring uniformity and effectiveness in the industry [21–24].

Table 10. Comments from survey questionnaire with themes and sub-themes.

No.	Questions	Findings	Main Themes and Sub-Themes
1	Are there specific areas of the plan that you believe require adjustments to comply with Egyptian BIM standards?	Management adjustments are needed, with emphasis on Document ownership, COBie compliance, Collaboration, interoperability, VDC/BIM adjustments, and BIM workflow adjustments.	Management Adjustments, Document Ownership, Standard Compliance
2	Are there components or processes in the workflow that you believe are unnecessary or overly complex for BIM mega projects in Egypt?	I am admirable by project, emphasizing the need for flexible standards, collaboration, tailored training, and effective change management.	Workflow Complexity, Training, and Change Management
3	What recommendations would you make to improve the BIM Execution Plan workflow for better suitability and efficiency in the context of Egyptian/MENA-region BIM mega projects?	Follow international standards, ensure LOD and stakeholder inclusion, simplify for easier implementation, standardize nationally, and include facility management early.	Standards and Stakeholder Engagement, Implementation Simplicity, National Standardization
4	Do you think the two subsections in the definition section of the proposed BEP Framework are sufficient?	Suggested additions include subsections on Technology Requirements, Stakeholder Roles and Responsibilities, and Data Management and Exchange Protocols.	Framework Comprehensiveness: Technology, Stakeholder Roles, Data Management
5	Do you think the three subsections in the BIM Project Execution Plan Overview section of the proposed BEP Framework are sufficient?	Suggested additions include Implementation Timeline, Performance Metrics, and Continuous Improvement Processes.	Framework Detailing: Implementation Schedule, Performance Evaluation, Improvement Processes
6	Do you think the seven subsections in the Project Information section of the proposed BEP Framework are sufficient?	Suggested additions include Sustainability Goals, Risk Management Strategies, and Change Management Procedures.	Information Sufficiency: Environmental, Risk, Change Management
7	Do you think the six subsections in the Management section of the proposed BEP Framework are sufficient?	Suggested additions include Quality Assurance/Quality Control Procedures, Stakeholder Communication Plans, and Technology Integration Strategies.	Management Robustness: QA/QC, Communication, Technology Integration
8	Do you think the four subsections in the Project Goals/BIM Uses section of the proposed BEP Framework are sufficient?	Suggested additions include Environmental Sustainability, Lifecycle Management, and Stakeholder Engagement Objectives.	Project Goals Depth: Sustainability, Lifecycle, Stakeholder Engagement
9	Do you think the six subsections in the Technical Requirements section of the proposed BEP Framework are sufficient?	Suggested additions include Cybersecurity Measures, Interoperability Standards, and Data Archiving and Retrieval Procedures.	Technical Adequacy: Cybersecurity, Interoperability, Data Management

Table 10. *Cont.*

No.	Questions	Findings	Main Themes and Sub-Themes
10	Do you think the eleven subsections in the Quality Assurance/Quality Control Plan section of the proposed BEP Framework are sufficient?	Suggested additions include Continuous Improvement Mechanisms, Stakeholder Feedback Loops, and Compliance with International Standards.	QA/QC Expansion: Continuous Improvement, Stakeholder Feedback, Standards Compliance
11	Please provide any additional comments or suggestions regarding the BIM Execution Plan workflow.	Suggestions for the BEP to become a pivotal document in Egypt, with calls for specific sections and emphasis on adaptability, collaboration, and integration with contracts.	BEP as Pivotal Document: Specific Sections, Adaptability, Stakeholder Collaboration

4. Discussion

The results of this study demonstrate a strong agreement among construction experts regarding the crucial importance of building information modeling (BIM) execution plans (BEPs) in large-scale construction projects. The survey data demonstrate a notable consistency in the perceived significance of various sections of BEPs, irrespective of respondents' experience levels. The Management and Project Goals/BIM Uses sections stand out for consistently receiving high-importance ratings.

4.1. Analysis within the Framework of Prior Research

Upon comparing these findings with prior research, it becomes apparent that the significance of organized management and well-defined project objectives corresponds with the wider body of literature on project management and BIM implementation. Prior studies have highlighted the importance of well-defined responsibilities and standardized procedures to improve the results and effectiveness of construction projects that utilize building information modeling (BIM). The present study strengthens this perspective by empirically verifying these factors through input from the industry, emphasizing a widespread acknowledgment of their significance across various levels of expertise.

4.2. Proposed Hypotheses for Investigation

The proposed hypotheses suggested that the use of standardized and adaptable BIM execution plans would be crucial for enhancing efficiency and effectively handling the intricacies of large-scale construction projects. The survey results confirm these hypotheses, as the data show a significant dependence on best execution practices (BEPs) for the success of projects. The results also suggest the need for more standardized practices, especially in the initial stages of projects, to reduce inefficiencies and misalignments.

4.3. Significance of Results

The results indicate that although the significance of BEPs is acknowledged, there are deficiencies in their prompt incorporation and uniformity across projects. This misalignment may result in inefficiencies and a lack of coherence in project implementation. Hence, it is evident that there is a requirement to promote a uniform methodology for BEPs, while also accommodating the flexibility to cater to individual project requirements and regional norms. This may entail creating a more extensive framework for the implementation of BEPs that incorporate the most effective methods identified in this and prior research.

4.4. The Developed Framework

The "Developed Framework" delineates the organized elements of a building information modeling (BIM) execution plan (BEP) for extensive construction projects. The framework is methodically structured into multiple primary sections, each focusing on distinct aspects of BIM execution planning. The steps are outlined in the table, presented in a simplified manner for better understanding:

The following are the sequential stages of the developed framework:

4.4.1. Definition

- **Abbreviations**: Lists standard abbreviations used within the plan.
- **Other Definitions**: Provides definitions of key terms relevant to the project.

4.4.2. BIM Project Execution Plan Overview:

- **Executive Summary**: Brief overview of the BIM execution strategy.
- **Vision Statement**: Outlines the project's vision and strategic goals.
- **References**: Lists documents, standards, and resources referenced in the BEP.

4.4.3. Project Information:

- **Project Description**: General description of the project.
- **Project Stakeholders**: Identification of all parties involved in the project.
- **Project Scope of Work in Details**: Detailed scope including tasks and deliverables.
- **Project Masterplan, Buildings Key Plan, Key Project Contacts, Key Project**
- **BIM Management**: Layouts and contact information essential for project management.

4.4.4. Management:

- Project Phases/Milestones, Key Roles and Responsibilities, Project Deliverables, Project Information Model Delivery Strategy, Task Information Delivery Plan (TIDP), Master Information Delivery Plan (MIDP): Detailed management plans outlining the project timeline, responsibilities, deliverables, and information delivery strategies

4.4.5. Project Goals/BIM Uses:

- Major BIM Uses, Level of Information Needed (LOIN), Level of Development (LOD), Level of Information (LOI): Specifies the BIM usage goals and the required levels of information and development.

4.4.6. Model Process and Project Standards (Methods and Procedure):

- Volume Strategy, Project Models Breakdown, Naming Conventions, Annotations, Dimensions, Abbreviations and Symbols "Drawing Standards", Project Units and Datum, Model Authoring: Standards and procedures for model creation and management.

4.4.7. Quality Assurance/Quality Control (QA/QC) Plan:

- Detailed QA/QC processes like design content check, visual/coordination check, standards check, interference check, clash criteria, model size, model warnings, information exchange, coordination process, and clash matrix.

4.4.8. Collaborations:

- **Collaboration Strategy, Schedule of Information Exchange, Schedule of Meetings, Common Data Environment (CDE):** Framework for collaboration among stakeholders, including schedules and data sharing environments.

4.4.9. Technical Requirements:

- **Exchange Formats, Software Needs/Scope, Hardware Needs, Data Security, IT Upgrades, Training**: Specifies the technical requirements including software, hardware, data security measures, and necessary training.

4.4.10. Integration of Emerging Technologies According to the Project BIM Uses

- **IoT Integration**
    - Sensor Deployment: Specify sensor types and locations.
    - Data Protocols: Define data collection and communication standards.
- **Digital Twin Development**
    - Modeling Guidelines: Establish standards for creating and maintaining digital twins.

- Simulation Tools: Identify tools for performance simulation and analysis.
- **Advanced Data Management**
  - Data Storage: Specify storage solutions and protocols.
  - Data Security: Implement security measures and compliance protocols.
- **VR Integration:**
  - Hardware and Software: Specify the VR hardware (e.g., headsets) and software platforms to be used.
  - Model Preparation: Define standards for preparing BIM models for VR environments, ensuring they are optimized for performance.
- **AR Integration:**
  - Devices and Applications: Specify AR devices (e.g., tablets, AR glasses) and software applications.
  - Data Overlay Standards: Establish guidelines for creating and managing AR content, including real-time data overlays from BIM models.
- **Training and Continuous Improvement**
  - Training Programs: Outline training for project teams.
  - Pilot Projects: Describe pilot implementation plans and feedback mechanisms.

5. Implementation of the Proposed BEP Framework in Real-World Projects

The proposed framework for standardizing building information modeling (BIM) execution plans (BEPs) provides a structured approach to enhance collaboration, efficiency, and consistency in large-scale construction projects. Here are practical steps and considerations for practitioners aiming to implement this framework in real-world projects:

5.1. Initial Assessment and Planning

Project Evaluation: Begin by assessing the specific needs and characteristics of the project. Understand the scope, complexity, and key stakeholders involved.

Customization: Tailor the standardized BEP framework to fit the unique requirements of the project. Customize elements such as project goals, roles, collaboration procedures, and technical requirements based on the project's context.

5.2. Stakeholder Engagement

Collaborative Workshops: Conduct workshops with all key stakeholders, including project managers, architects, engineers, contractors, and clients. These sessions should aim to align everyone on the BEP objectives, processes, and roles.

Roles and Responsibilities: Clearly define the roles and responsibilities of each stakeholder within the BEP. Ensure that everyone understands their tasks and the overall workflow.

5.3. Framework Implementation

Documentation: Create a comprehensive BEP document that includes all necessary sections such as project information, goals, BIM uses, collaboration procedures, model structure, and quality control.

Technology Integration: Identify and integrate the necessary technologies and software tools that support the BEP. This includes BIM software such as Autodesk Products version 2024 and Autodesk Construction Cloud, data management systems, and collaboration platforms.

5.4. Training and Capacity Building

BEP Training Programs: Develop and conduct training programs for all stakeholders to ensure they are proficient in using the BEP and associated technologies. Training should cover the use of BIM tools, data-exchange protocols, and quality control measures [24].

Continuous Learning: Encourage a culture of continuous learning and improvement. Keep stakeholders updated with the latest advancements in BIM technologies and best practices.

5.5. Quality Assurance and Control

Regular Audits: Implement regular audits and reviews of the BEP implementation. This includes checking compliance with the BEP guidelines, ensuring data integrity, and evaluating the effectiveness of collaboration procedures [2,11,26,27].

Feedback Mechanisms: Establish feedback loops where stakeholders can report issues, suggest improvements, and share their experiences. Use this feedback to make iterative improvements to the BEP.

5.6. Monitoring and Evaluation

Performance Metrics: Define clear performance metrics to monitor the success of the BEP implementation. These metrics should cover aspects such as project timelines, cost savings, quality of deliverables, and stakeholder satisfaction.

Benchmarking: Compare the project's performance against industry benchmarks and best practices. This helps in identifying areas of improvement and showcasing the benefits of the standardized BEP framework.

5.7. Case Studies and Best Practices

Documenting Case Studies: Document case studies of successful BEP implementations to serve as references for future projects. Highlight the challenges faced, solutions implemented, and the overall impact on project outcomes.

Sharing Best Practices: Share best practices and lessons learned within the organization and with the wider industry. This promotes knowledge transfer and continuous improvement in BEP implementation.

5.8. Adaptation to Regional Standards

Local Compliance: Ensure that the BEP framework complies with local standards and regulations. This includes aligning with regional BIM standards, contractual requirements, and construction practices.

Regional Customization: Adapt the framework to address specific regional challenges and opportunities. This might involve incorporating local construction methods, materials, and stakeholder expectations.

6. Conclusions

This study embarked on an extensive exploration of building information modeling (BIM) execution plans (BEPs) within the mega construction sector, revealing critical insights into the current practices, challenges, and the imperative need for standardized processes. Through the administration of a comprehensive questionnaire among 87 industry professionals, the study highlighted a strong consensus on the essential nature of structured and standardized BEPs to effectively tackle the complexities of large-scale projects.

The findings underscore several key points:

Critical Importance of BEPs: The survey data demonstrate a notable consistency in the perceived significance of various sections of BEPs, irrespective of respondents' levels of experience. The Management and Project Goals/BIM Uses sections consistently received high importance ratings, emphasizing the necessity of organized management and well-defined objectives in navigating the intricacies of mega projects.

Challenges and Gaps: Despite the acknowledged importance of BEPs, the study revealed significant gaps in their early integration and uniformity across projects. These misalignments can lead to inefficiencies and a lack of coherence in project implementation. The feedback from the survey indicated a need for substantial improvements in aligning

BEPs with local standards, improving document management, and promoting collaborative practices.

Proposed Framework: To address these challenges, the study developed a comprehensive BEP framework based on empirical data and professional feedback. This framework integrates best practices from 36 BEP documents sourced from diverse international organizations, ensuring global applicability while allowing for regional customization. Key elements of the framework include detailed management structures, project goals, roles and responsibilities, collaboration procedures, model structure, and quality control measures.

Validation and Practical Application: The proposed framework was validated through empirical data collected from industry professionals. The practical implementation steps outlined in the study, including stakeholder engagement, training programs, and regular quality audits, provide a roadmap for practitioners to enhance collaboration, reduce inefficiencies, and improve project outcomes in real-world projects.

Future Research Directions: While this study makes significant contributions to the field of BIM implementation, continuous efforts are required to ensure the effective application of BEPs across different project stages and contexts.

In conclusion, this research contributes to the ongoing discussion on enhancing BIM implementation in large-scale construction by presenting a novel, empirically validated framework for the standardization of BEPs. By addressing both global and regional challenges, this framework enhances the efficiency and effectiveness of project management in the AECO industry, laying the groundwork for more efficient, collaborative, and technology-integrated construction project management.

Author Contributions: Conceptualization, A.M.A. and A.S. (Alaa Sherif); Data curation, A.M.A. and K.S.; Formal analysis, A.M.A. and K.S.; Funding acquisition, A.M.A.; Investigation, A.M.A. and K.S.; Methodology, A.M.A.; Project administration, A.M.A.; Resources, A.M.A. and A.A.A.; Software, A.M.A. and K.S.; Supervision, A.M.A. and A.S. (Alaa Sherif); Validation, A.M.A., K.S., A.A.A., A.S. (Amna Shibeika) and A.S. (Alaa Sherif); Visualization, A.M.A., K.S. and A.A.A.; Writing—original draft, A.M.A. and K.S.; Writing—review and editing, A.M.A., K.S., A.A.A., A.S. (Amna Shibeika) and A.S. (Alaa Sherif). All authors have read and agreed to the published version of the manuscript.

Funding: The authors extend their appreciation to the Researchers Supporting Project number (RSPD2024R590), King Saud University, Riyadh, Saudi Arabia.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the corresponding authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Web of Science Documents

BIM, BIM Execution plan, BIM (Topic) and 2020 or 2021 or 2022 or 2023 or 2024 (Publication Years) and Engineering Civil or Construction Building Technology or Engineering Multidisciplinary (Web of Science Categories) and Engineering or Construction Building Technology (Research Areas) and English (Languages) and Engineering (Research Areas) and 2020 or 2021 or 2022 or 2023 or 2024 (Publication Years) and Construction Building Technology (Research Areas) and Doctor Of Philosophy, Engineering Christian Correa Becerra (Exclude â Researcher Profiles) and Construction Building Technology (Web of Science Categories) and Construction Building Technology (Web of Science Categories) and Construction Building Technology or Engineering Civil or Management (Web of Science Categories) and Construction Building Technology or Engineering (Research Areas) and 2020 or 2021 or 2022 or 2023 or 2024 (Publication Years) and Engineering Civil or Construction Building Technology or Engineering Industrial (Web of Science Categories).

Title	Authors
Development and application of a specification-compliant highway tunnel facility management system based on BIM	Chen, Lijuan; Shi, Peixin; Tang, Qiang; Liu, Wei; Wu, Qinglin
Change detection for indoor construction progress monitoring based on BIM, point clouds and uncertainties	Meyer, Theresa; Brunn, Ansgar; Stilla, Uwe
Digital twin-enabled real-time synchronization for planning, scheduling, and execution in precast on-site assembly	Jiang, Yishuo; Li, Ming; Li, Mingxing; Liu, Xinlai; Zhong, Ray Y.; Pan, Wei; Huang, George Q.
Mixed integer programming for dynamic tower crane and storage area optimization on construction sites	Riga, Katrin; Jahr, Katrin; Thielen, Clemens; Borrmann, Andre
Barriers to BIM-Based Life Cycle Sustainability Assessment for Buildings: An Interpretive Structural Modelling Approach	Onososen, Adetayo; Musonda, Innocent
BIM-based semantic building world modeling for robot task planning and execution in built environments	Kim, Kyungki; Peavy, Matthew
Visual and Virtual Production Management System for Proactive Project Controls	Lin, Jacob J.; Golparvar-Fard, Mani
IFC-based process mining for design authoring	Kouhestani, Sobhan; Nik-Bakht, Mazdak
Construction workspace management: critical review and roadmap	Igwe, Charles; Nasiri, Fuzhan; Hammad, Amin
Crane-lift path planning for high-rise modular integrated construction through metaheuristic optimization and virtual prototyping	Zhu, Aimin; Zhang, Zhiqian; Pan, Wei
Building Information Modelling- (BIM-) Based Generative Design for Drywall Installation Planning in Prefabricated Construction	Lobo, Jose Daniel Cuellar; Lei, Zhen; Liu, Hexu; Li, Hong Xian; Han, SangHyeok
Chronographical spatiotemporal dynamic 4D planning	Mazars, Thibault; Francis, Adel
Hybrid Genetic Algorithm and Constraint-Based Simulation Framework for Building Construction Project Planning and Control	Mahdavian, Amirsaman; Shojaei, Alireza
A Serious Gaming Approach to Integrate BIM, IoT, and Lean Construction in Construction Education	Teizer, Jochen; Golovina, Olga; Embers, Stephan; Wolf, Mario
Qualitative Analysis of the Impact of Contracts on Information Management in AEC Projects	Celoza, Amelia; de Oliveira, Daniel P.; Leite, Fernanda
Implementation of BIM Virtual Models in Industry for the Graphical Coordination of Engineering and Architecture Projects	Fernandez Rodriguez, Juan Francisco
Multistage self-adaptive decision-making mechanism for prefabricated building modules with IoT-enabled graduation manufacturing system	Ding, Haora; Li, Mingxing; Zhong, Ray Y.; Huang, George Q.
Integrating BIM and ABS for Multi-Crane Operation Planning through Enabling Safe Concurrent Operations	Khodabandelu, Ali; Park, JeeWoong
Measuring Progress and Productivity in Model-Driven Engineering for Capital Project Delivery	Garcia, Gustavo; Golparvar-Fard, Mani; de la Garza, Jesus M.; Fischer, Martin
Assessing the Duration of the Lead Appointed Party Coordination Tasks and Evaluating the Appropriate Team Composition on BIM Projects	Mayer, Pavol; Funtik, Tomas; Erdelyi, Jan; Honti, Richard; Cerovsek, Tomo
Data fusion approach for a digital construction logistics twin	Gehring, Maximilian; Rueppel, Uwe
Integration of Augmented Reality and Building Information Modeling for Enhanced Construction Inspection-A Case Study	Pan, Nai-Hsin; Isnaeni, Nurani Nanda
Unlocking the Potential of Digital Twins in Construction: A Systematic and Quantitative Review Using Text Mining	Park, Jisoo; Lee, Jae-Kang; Son, Min-Jae; Yu, Chaeyeon; Lee, Jaesung; Kim, Sungjin
Impact of Risk Assessment in Project Execution and Its Mitigation Strategies Using Modern Automation	Shendurkar, Praddyumna Shrikrishna; Jain, Mayur Shirish; Sudarsan, J. S.
BIM-based task planning method for wheeled-legged rebar binding robot	Cao, Siyi; Duan, Hao; Guo, Shuai; Wu, Jiajun; Ai, Tengfeng; Jiang, Haili
Analyzing the Variances in Perspectives on BIM Implementation among Korea AEC Participants	Shin, Min Ho; Kim, Seong-Ah
The Status of Building Information Modeling Adoption in Slovakia	Funtik, Tomas; Makys, Peter; Dubek, Marek; Erdelyi, Jan; Honti, Richard; Cerovsek, Tomo
Integrating BIM Processes with LEED Certification: A Comprehensive Framework for Sustainable Building Design	Di Gaetano, Federico; Cascone, Stefano; Caponetto, Rosa
Development of a Performance Index Model for Evaluation of BIM-Based Stakeholder Management Using Fuzzy Synthetic Evaluation	Gaur, Sulakshya; Tawalare, Abhay
BIM Modelling of the AQP Touristic Cycle Path	Pazzini, Margherita; Cameli, Leonardo; Lantieri, Claudio; Vignali, Valeria; Mingozzi, Daniele; Crescenzo, Giuseppe

Title	Authors
A Literature Review on the Usage of Ontologies for Quality Management in the Construction Execution Phase	Seiss, S.
Strategies for Rule-Based Generated Assembly Sequences in Large-Scale Plant Construction	Weber, Jan; Koenig, Markus
Planning BIM-Based Design Projects: A Product-Process Framework	Abou-Ibrahim, Hisham; Hamzeh, Farook
Strategies of BIM Application with Traditional Project Delivery Method: A Case of Building Construction Industry in Pakistan	Din, Zia Ud; Ather, Waqas; Gibson, G. Edward, Jr.
A Critical Review of Visual Aid Implementation in Lean Construction Scheduling Process	Pratama, Lucky Agung; Dossick, Carrie Sturts
A Building Information Modeling Approach for Adaptive Reuse Building Projects	Sanchez, Benjamin; Bindal-Gutsche, Christoph; Hartmann, Timo; Haas, Carl

Appendix B. Scopus Documents

Authors	Title	Year
Hou Y.; Volk R.	Conceptual design of a digital twin-enabled building envelope energy audits and multi-fidelity simulation framework for a computationally explainable retrofit plan	2022
Noor R.N.; Ibrahim C.K.I.C.; Belayutham S.	Making Sense of Multi-Actor Social Collaboration in Building Information Modelling Level 2 Projects: A Case in Malaysia	2021
Park K.-J.; Ock J.-H.	Structuring a BIM Service Scoping, Tendering, Executing, and Wrapping-Up (STEW) Guide for Public Owners	2022
Kouhestani S.; Nik-Bakht M.	IFC-based process mining for design authoring	2020
Din Z.U.; Ather W.; Gibson G.E.	Strategies of BIM Application with Traditional Project Delivery Method: A Case of Building Construction Industry in Pakistan	2020
Mellenthin Filardo M.; Walther T.; Maddineni S.; Bargstädt H.-J.	Installing Reinforcement Rebars Using Virtual Reality and 4D Visualization	2021
Smetankova J.; Duris A.; Rucinsky R.; Mesaros P.; Zemanova L.	Construction proceedings in the Slovak Republic: An overview of tools for efficient exchange and management of information in the BIM environment	2023
James D.; Sabu B.; James D.	BIM Implementation Strategy- A proposal for KMRL	2023
Celoza A.; De Oliveira D.P.; Leite F.	Role of BIM Contract Practices in Stakeholder BIM Implementation on AEC Projects	2023
Wan Siti Hajar W.N.; Syahrul Nizam K.; Nurshuhada Z.	Systematic Review: Information for FM-Enabled BIM	2022
Olugboyega O.; Windapo A.	Investigating the Strategic Planning of BIM Adoption on Construction Projects in a Developing Country	2022
Mohanaraj R.; Ganeshu P.; Gowsiga M.	Enhance the collaborative involvement of stakeholders through cloud-based Bim in the Srilanka construction industry	2022
Singh J.; Anumba C.J.	Real-time pipe system installation schedule generation and optimization using artificial intelligence and heuristic techniques	2022
Yung A.T.B.; Aminudin E.; Liat C.N.S.; Neardey M.; Zakaria R.; Hamid A.R.A.; Ahmad F.; Yong L.Y.	Adoption of Building Information Modelling in Malaysia Road Construction	2020
Lechhab N.; Iordanova I.; Forgues D.	Evaluation of the Return on Investment of BIM—The Case of an Architectural Firm	2023
Sekhar A.; Maheswari J.U.	Construction Research Congress 2022	2022
Tschickardt T.; Kaufmann F.; Glock C.	Lean and bim-based flight planning for automated data acquisition of bridge structures with lidar uav during construction phase	2022
Abbas M.A.; Ajayi S.O.; Oyegoke A.S.; Alaka H.	A cloud-based collaborative ecosystem for the automation of BIM execution plan (BEP)	2024
Chen L.; Shi P.; Tang Q.; Liu W.; Wu Q.	Development and application of a specification-compliant highway tunnel facility management system based on BIM	2020
Filardo M.M.; Akula R.; Walther T.; Bargstädt H.-J.	Automated framework for optimized path-planning for pile foundation drilling machines based on 4D BIM modelling	2021

Authors	Title	Year
Valinejadshoubi M.; Moselhi O.; Iordanova I.; Valdivieso F.; Shakibabarough A.; Bagchi A.	The Development of an Automated System for a Quality Evaluation of Engineering BIM Models: A Case Study	2024
Nashruddin S.N.H.A.B.M.; Herman S.S.; Nashruddin S.N.A.B.M.; Ismail S.; Ling S.M.	Harnessing Geographic Information System (GIS) by Implementing Building Information Modelling (BIM) to Improve AEC Performance Towards Sustainable Strategic Planning in Setiu, Terengganu, Malaysia	2024
Das N.; Akshatha K.; Hannah Jessie Rani R.	5G Pathway Navigation for Smart Infrastructure	2023
Ibrahim A.; Golparvar-Fard M.; El-Rayes K.	Multi-objective Optimization of Reality Capture Plans for Computer Vision-Driven Construction Monitoring with Camera-Equipped UAVs	2022
Panagiotidou N.; Pitt M.; Lu Q.	Building information modelling execution plans: A global review	2022
Mayer P.; Funtík T.; Erdélyi J.; Honti R.; Cerovšek T.	Assessing the duration of the lead appointed party coordination tasks and evaluating the appropriate team composition on bim projects	2021
Mirarchi C.; Lupica Spagnolo S.; Daniotti B.; Pavan A.	Structuring general information specifications for contracts in accordance with the UNI 11337:2017 standard	2020
Muhammad I.; Ying K.; Nithish M.; Xin J.; Xinge Z.; Cheah C.C.	Robot-Assisted Object Detection for Construction Automation: Data and Information-Driven Approach	2021
Anderson A.; Ramalingam S.	A socio-technical intervention in bim projects—An experimental study in global virtual teams	2021
Amany A.; Taghizade K.; Noorzai E.	Investigating conflicts of expert contractors using the last planner system in building information modeling process	2020
Chai C.; Tang J.T.; Chan S.; Lee C.; Goh K.	BIM integration in agile scrum during the design phase	2023
Di Gaetano F.; Cascone S.; Caponetto R.	Integrating BIM Processes with LEED Certification: A Comprehensive Framework for Sustainable Building Design	2023
Savin I.M.; Sinenko S.A.	Experience in digitizing the services of public authorities in the transport sector	2020
Heesom D.; Boden P.; Hatfield A.; Rooble S.; Andrews K.; Berwari H.	Developing a collaborative HBIM to integrate tangible and intangible cultural heritage	2021
Mahbod S.; Iordavona I.; Poirier E.	A Gap Analysis of Current CCDC Standard Contract Documents and Provisions for Successful BIM-Enabled Projects in Canada	2023
Funtík T.; Makýš P.; Ďubek M.; Erdélyi J.; Honti R.; Cerovšek T.	The Status of Building Information Modeling Adoption in Slovakia	2023
Placzek G.; Barking L.; Troitzsch H.; Schwerdtner P.	Aktionsplan zur modellbasierten Baulogistikplanung—Die Implementierung BIM-basierter Planungsmethoden in die Fachdisziplin Baulogistik erfordert Handlungsbedarf	2022
Richert C.; Hanek D.	Approved standards of formwork and reinforcement plans; [Bewährte Standards der Schal- und Bewehrungsplanung]	2020
Ajayi S.O.; Oyebiyi F.; Alaka H.A.	Facilitating compliance with BIM ISO 19650 naming convention through automation	2023
Gächter W.; Exenberger H.; Fasching A.; Hillisch S.; Mulitzer G.; Seywald M.; Rettenbacher M.; Fleischmann G.; Fröch G.; Flora M.	Possible applications for a digital ground model in infrastructure construction; [Anwendungsmöglichkeiten eines digitalen Baugrundmodells im Infrastrukturbau]	2021
Keung C.C.W.; Fok W.H.	The application of Bim in the undergraduate course integrated building project development	2021
Pazzini M.; Cameli L.; Lantieri C.; Vignali V.; Mingozzi D.; Crescenzo G.	BIM Modelling of the AQP Touristic Cycle Path	2023
Magursi L.; Zurlo R.; Sorbello R.	Dynamic evaluation of the top-down construction of the Belfiore high-speed railway station	2022
Celoza A.; de Oliveira D.; Leite F.	Association of BIM-Related Contract Language and BIM Use on Construction Projects	2023
Celoza A.; De Oliveira D.P.; Leite F.	Qualitative Analysis of the Impact of Contracts on Information Management in AEC Projects	2023
Garcia G.; Golparvar-Fard M.; De La Garza J.M.; Fischer M.	Measuring Progress and Productivity in Model-Driven Engineering for Capital Project Delivery	2021
Soon L.T.; Ng Z.X.; Kamarazaly M.A.; Kam K.J.	The analysis of Bim based measurement for the quantity surveying profession	2023
Cardoso L.R.A.; Rios T.M.L.; Mognhol T.Z.; Marostica A.V.	Strategic Planning of Work and the Use of 4D BIM for Multiple Floor Buildings	2021

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Liang C.J.; McGee W.; Menassa C.C.; Kamat V.R.	Bi-directional communication bridge for state synchronization between digital twin simulations and physical construction robots	2020
Oraee M.; Hosseini M.R.; Edwards D.; Papadonikolaki E.	Collaboration in BIM-based construction networks: a qualitative model of influential factors	2022
Alvarez A.A.; Ripoll-Meyer M.V.	Proposal for the implementation of the bim methodology in an classroom experience focused on building sustainability; [Propuesta para la implementación de la metodologia bim en una experiencia áulica orientada a la sustentabilidad edilicia]	2020
Oyedira H.; Turner W.; Kim K.	Information Modeling for 4D BIM-Based Construction Robot Task Planning and Simulation	2024
Mohan N.; Gross R.; Menzel K.; Theis F.	Opportunities and challenges in the implementation of building information modelling for prefabrication of heating, ventilation and air conditioning systems in small and medium-sized contracting companies in Germany: a case study	2021
Marzouk M.; Ayman R.; Alwan Z.; Elshaboury N.	Green building system integration into project delivery utilising BIM	2022
Celoza A.; Leite F.; De Oliveira D.P.	Impact of bim-related contract factors on project performance	2021
Sigalov K.; König M.	BIM contracts—Secure digital transactions in the construction industry; [BIM-contracts—sichere digitale Transaktionen in der Baubranche]	2023
Hassanain M.A.; Akbar A.E.; Sanni-Anibire M.O.; Alshibani A.	Challenges of utilizing BIM in facilities management in Saudi Arabia	2023
Khawaja E.U.R.; Mustapha A.	Mitigating Disputes and Managing Legal Issues in the Era of Building Information Modelling	2021
Mahdavian A.; Shojaei A.	Hybrid Genetic Algorithm and Constraint-Based Simulation Framework for Building Construction Project Planning and Control	2020
Seiß S.	A Literature Review on the Usage of Ontologies for Quality Management in the Construction Execution Phase	2021
Bragadin M.A.; Guardigli L.; Calistri M.; Ferrante A.	Demolishing or Renovating? Life Cycle Analysis in the Design Process for Building Renovation: The ProGETonE Case	2023
Rahim N.S.A.; Ismail S.; Subramaniam C.; Abdullah Habib S.N.H.; Durdyev S.	Building Information Modelling Strategies in Sustainable Housing Construction Projects in Malaysia	2023
Tuval E.; Isaac S.	Online Planning and Management of Design Coordination Tasks with BIM: Challenges and Opportunities	2022
Oliveira F.M.; Santos E.T.	A survey on BIM information management: The approach of producers and consumers of model information in Brazil	2022
Shin M.H.; Kim S.-A.	Analyzing the Variances in Perspectives on BIM Implementation among Korea AEC Participants	2024
Ayerra I.; Castronovo F.; Ventura S.M.; Nikolic D.	Next steps in Bim execution planning: a review of guides in the USA	2021
Traverso-Frisancho A.; Romero-Alva V.	Application of BIM Methodology in Public and Private Electricity and Telecommunications Projects in Peru	2023
Fernández Rodríguez J.F.	Implementation of BIM Virtual Models in Industry for the Graphical Coordination of Engineering and Architecture Projects	2023
Oreto C.; Biancardo S.A.; Veropalumbo R.; Viscione N.; Russo F.; Dell'acqua G.	BIM–LCCA Integration for Road Pavement Maintenance	2022

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