

Research Article

# Bibliometric Study on the Determinants of Building Design Management Practice

Adamu Ajahunegn Agegn<sup>1,\*</sup> , Meseret Getnet Meharie<sup>2</sup> , Getahun Fetene Dinku<sup>1</sup>

<sup>1</sup>Department of Construction Technology and Management, University of Gondar, Gondar, Ethiopia

<sup>2</sup>Department of Building Construction Technology, FDRE Technical and Vocational Training Institute, Addis Ababa, Ethiopia

## Abstract

Design management plays a critical role in overseeing the design process and fostering effective collaboration within organizations, yet its conceptual understanding remains fragmented due to limited cohesive research literature. To address this gap, this study conducts a bibliometric analysis of the determinants of building design management practices, aiming to provide insights that enhance design management in building projects. Utilizing web-based data collection, scientific articles from specialized construction industry journals were analyzed through performance analysis and scientific mapping, with data clustering and visualization conducted using Visualization of Similarities Viewer (VOSviewer version 1.6.18). The findings identify key determinants such as building energy management, building type and users, building information modeling, design management services, project management, and sustainable design and value engineering, alongside challenges including integration and collaboration issues, operational and maintenance difficulties, information and communication gaps, design quality concerns, reduced trust levels, and ambiguities in roles and responsibilities. This study underscores the evolving nature of building design management, emphasizes the need to improve design quality, and offers recommendations for regulatory bodies, project managers, and design managers, while suggesting future research directions.

## Keywords

Bibliometric, Building, Challenges, Design Management, Determinant

## 1. Introduction

The construction industry drives economic and social progress by creating jobs, boosting infrastructure, and improving quality of life. It enhances connectivity, adopts sustainable technologies, and supports community development through housing. By focusing on skills development and local engagement, it fosters inclusive growth and contributes to resilient, long-term prosperity [1].

Construction projects are inherently complex, often facing

disagreements, delays, and cost overruns due to intricate requirements, regulatory compliance, diverse stakeholders, and unpredictable conditions. Conflicts among contractors, designers, and clients further heighten risks, while material availability, weather, and site-specific factors contribute to uncertainty. Effective project management, clear communication, and proactive risk mitigation are crucial for achieving successful outcomes [2].

\*Corresponding author: [adamu.ajahunegn@uog.edu.et](mailto:adamu.ajahunegn@uog.edu.et) (Adamu Ajahunegn Agegn)

**Received:** 6 November 2024; **Accepted:** 21 November 2024; **Published:** 7 December 2024



Copyright: © The Author(s), 2024. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

Productivity in the AEC industry suffers from poor design management, which leads to delays and errors. Effective design management should focus on collaboration, communication, and technology like BIM to improve coordination and creativity, thus boosting productivity [3].

The Architecture, Engineering, and Construction (AEC) industry is evolving to tackle sustainability, energy efficiency, and climate change. This shift increases complexity, driven by the need for eco-friendly designs and advanced technologies. Green building standards and renewable energy are becoming standard, while innovations like Building Information Modeling (BIM) and advanced materials improve project outcomes. As climate risks rise, AEC professionals must focus on designing resilient infrastructure, emphasizing collaboration, interdisciplinary approaches, and ongoing education to advance the industry [4].

Design management aligns architectural projects with goals, client expectations, and standards. It includes planning, team coordination, quality assurance, and risk management. Design managers facilitate collaboration among architects, engineers, and clients, balancing creativity with feasibility. Embracing advanced technologies and sustainable practices will be crucial for future success in architectural design [5].

Sebastian's view is spot on. Architectural design indeed involves managing a complex interplay of technical expertise, client expectations, functional and aesthetic needs, and stakeholder interactions. Success in this field hinges on strong leadership, effective collaboration, and a proactive approach to these multifaceted challenges (Tzortzopoulos & Cooper, 2007).

Gray and Hughes define design management as a distinct field that integrates managerial and design elements during a project's design phase. This role involves specialized skills to align design with project goals, client expectations, and industry standards. Design managers enhance project outcomes by facilitating collaboration, optimizing resources, controlling costs, and mitigating risks, thus emphasizing its critical role in driving innovation and excellence in the architectural, engineering, and construction industries [2].

Sinclair defines design management as overseeing and coordinating the design process, including setting objectives, planning, resource allocation, and leading teams. Design managers ensure alignment with project goals, client expectations, and industry standards, highlighting their critical role in achieving project success and delivering value in the AEC industries [4].

Embracing advanced technologies like BIM, virtual reality, and robotics is crucial for improving efficiency and sustainability in construction. These innovations address urbanization, population growth, and climate change, driving progress and ensuring long-term project success [7].

As integration challenges between design and construction continue, construction companies are increasingly assuming design management roles. This shift improves collaboration, streamlines workflows, and enhances communication be-

tween design and construction teams. By leveraging their project management expertise, these firms optimize the design process, aligning with project goals and client expectations. This approach boosts efficiency, reduces risks, and adds value for clients [8].

Tombesi and Whyte define design management in construction through two key dimensions. The first dimension involves coordinating specialized expertise within consulting firms during the pre-construction phase to ensure cohesive design solutions. The second dimension focuses on managing the transition between design and construction phases, facilitating smooth communication and integration. Addressing both dimensions enhances project outcomes, reduces errors, and adds value for clients and stakeholders [9].

Design management is crucial for overseeing the design process and ensuring collaboration among stakeholders. It focuses on optimizing information flow and coordination between architects, engineers, consultants, clients, and contractors. Design managers align project objectives, manage resources, resolve conflicts, and maintain design consistency, enhancing quality and contributing to successful construction projects [10].

Integrating design into a company's core competencies requires effective design management. Design managers coordinate stakeholders, align efforts with company goals, and oversee the entire design process. They ensure quality and client satisfaction, facilitate team communication, and optimize resources. By managing timelines and mitigating risks, design managers drive innovation, enhance competitiveness, and support sustainable growth [11].

Traditional design management focuses on two main components: preparing the design team with skills and resources through training and mentorship, and enhancing design systems by streamlining workflows and using technology. This approach reduces errors, eliminates redundancies, and speeds up project delivery while maintaining quality. By emphasizing these aspects, design management ensures high-quality, efficient design solutions that meet client requirements and drive project success [10].

Indeed, despite its significance, building design management concepts have not received comprehensive research attention. Therefore, this study aims to bridge this gap by conducting a bibliometric examination of the determinants shaping building design management practices. By analyzing existing literature, identifying key themes, trends, and gaps in research, this study seeks to provide insights into the factors influencing building design management and contribute to the development of theoretical frameworks and practical guidelines in this area. Through a systematic review of scholarly publications, this research endeavor aims to enhance understanding of the challenges, opportunities, and best practices in building design management, ultimately facilitating more effective decision-making and implementation strategies in the construction industry.

The design phase of a building project demands precise

management. Effective design management ensures quality through strong leadership, coordination, and resource optimization. Poor management can lead to integration issues, delays, and increased costs. To avoid these risks, organizations should prioritize design management, invest in project systems, and foster collaboration. This approach ensures high-quality outcomes and successful project delivery [2].

Inconsistent design management among consultants has increased project costs and duration. Effective management is vital for timely completion, particularly with complex projects. Urgent education on design management methodologies is needed to address these complexities. Comprehensive training will help optimize processes, manage resources efficiently, and promote collaboration. Continuous learning will build a skilled workforce, drive innovation, and improve project efficiency [12].

Complexities in procurement, scheduling, and quality control often overshadow design management. However, effective design management is vital for meeting project objectives, addressing client expectations, and maintaining quality standards. Despite its challenges, prioritizing design management is essential for successful project outcomes and maximizing stakeholder value [13].

Effectively addressing design challenges simplifies tasks and smooths the transition to subsequent activities, like finalizing drawings. By clarifying requirements, identifying issues, and developing solutions, teams streamline workflows and enhance task clarity. A clear understanding of project objectives allows for better focus on completing documentation and meeting milestones. Project managers must stay vigilant and proactive to address emerging challenges and ensure ongoing success [14].

Modern design management methods, while innovative, often face fragmentation and lack a solid conceptual foundation. Rapid advancements in software and technology offer improved efficiency but can create inefficiencies and compatibility issues. The absence of a unified framework limits practical application. Addressing these challenges requires better integration, standardization, and the development of a robust conceptual foundation. A common framework and increased collaboration among practitioners, researchers, and industry stakeholders are essential to unlocking the full potential of modern design management and driving innovation [15].

Design management challenges often arise from the lack of a robust theoretical foundation. While design control is recognized as difficult, existing studies haven't provided a comprehensive framework for practical advancements. Historically, research has focused on the designer's perspective, overlooking broader organizational and project contexts. This gap can impede achieving design management goals. Research should explore how design management interacts with organizational dynamics, project requirements, and stakeholder interests. A holistic understanding of these factors can lead to more effective practices, fostering innovation,

enhancing collaboration, and improving outcomes in the built environment [6].

Gray and Hughes have significantly advanced building design management by focusing on coordinating design activities, integrating design with other project phases, and optimizing outcomes through design managers. Their comprehensive framework addresses challenges in complex construction projects, shaping contemporary approaches to design management. Their contributions guide practitioners, researchers, and educators in improving project delivery and design quality [16].

Articles covering various aspects of design management often originate from initial concepts, yet a comprehensive understanding of building design management remains elusive due to poorly organized research papers. This study seeks to address this gap by establishing foundational concepts and tackling associated problems in a structured manner. By synthesizing existing literature, identifying key themes, and clarifying terminologies, this research aims to provide a cohesive framework for understanding building design management. Additionally, the study intends to explore common challenges and propose practical solutions to enhance the effectiveness of design management practices in the construction industry. Through these efforts, the research endeavors to contribute to the development of a more coherent and comprehensive body of knowledge in the field of building design management, ultimately improving project outcomes and fostering innovation within the built environment.

The study aims to address the stated problem through the following specific objectives:

- 1) Explore key growth trends in research on building design management.
- 2) Investigate key areas of study within building design management.
- 3) Examine problems in building design management practice.

The article structure is organized into sections including an introduction, research methodology, results, and discussion. These sections are followed by a conclusion, recommendations, and future research directions, providing a comprehensive framework for addressing the objectives and contributing to the field of building design management.

## 2. Research Methodology

### 2.1. Data Collection Strategy

The research began by devising a strategy to collect relevant data, which involved determining the most appropriate databases and sources for gathering literature related to building design management. Keywords relevant to the topic were carefully selected to ensure comprehensive coverage of the literature, guiding searches across the chosen databases and sources for relevant articles and publications.

The data collection process primarily honed in on web-based sources, encompassing scientific articles and specialized periodicals within the Architecture, Engineering, and Construction (AEC) industry. These sources were carefully selected based on their direct relevance to the research topic and their potential to yield valuable insights into building design management practices. By concentrating efforts on these sources, the research aimed to gather a diverse range of perspectives and information essential for comprehensively exploring the intricacies of building design management.

These selected web-based sources were deemed valuable due to their focus on topics central to building design management and their potential to provide up-to-date and in-depth coverage of relevant issues. By leveraging these sources, the research sought to ensure the thoroughness and relevance of the collected data, facilitating a robust analysis of building design management practices and trends within the AEC industry.

## 2.2. Time Frame Selection

The research delved into papers published from 1997 to 2022, meticulously chosen after thorough analysis. This 25-year span was selected to provide a comprehensive understanding of the evolution of building design management. It allowed for a detailed exploration of trends and developments over time, offering insights into how practices have evolved and adapted within the field. By scrutinizing these patterns, the research aimed to discern the trajectory of building design management, uncovering shifts in focus, methodologies, and emerging themes.

Through this comprehensive analysis, the study sought to shed light on the current state of building design management and its potential future directions. By identifying emerging trends and themes, the research aimed to provide valuable insights for practitioners and researchers alike, informing strategic decision-making and guiding future advancements in the field.

Through this examination, the goal was to offer insights that could inform future research and practical applications in building design management. By understanding the evolving landscape of the field, the research aimed to provide valuable guidance for navigating its complexities and driving progress in both academic and professional domains.

## 2.3. Mapping and Bibliometric Analysis

Following data collection, the research entered into the mapping and bibliometric analysis phase, a critical stage aimed at systematically organizing and categorizing the amassed data. Leveraging advanced techniques, the research sought to methodically discern patterns, trends, and relationships among diverse research topics and themes within the realm of building design management.

Sophisticated methods like co-citation analysis and key-

word co-occurrence analysis were used to understand how building design management has changed over time. By digging into these details, the research aimed to give valuable insights into the field's development and current situation.

The study wanted to offer a clearer picture of how building design management has evolved and where it stands today. By uncovering hidden patterns and dynamics, the research aimed to provide helpful insights for researchers and practitioners, guiding their decisions and shaping future improvements in building design management.

Through this rigorous analysis, the study endeavored to identify key concepts, emerging trends, and unexplored areas for further investigation within the dynamic landscape of building design management. By shedding light on these facets, the research aimed to contribute to the advancement and enrichment of scholarly discourse in the field, fostering a deeper understanding and guiding future research endeavors.

This research methodology was carefully designed to explore building design management thoroughly. By combining data collection with advanced mapping and bibliometric analysis, the study aimed to uncover valuable insights that could advance both research and practical applications in the field.

Figure 1 illustrates the exploration of key growth trends in research on building design management, including the distribution of articles, prominent journals, and relationships among countries and authors. The second objective involved investigating key areas of study within building design management through a systematic literature review. Finally, the third objective focused on exploring problems in building design management practice, which was successfully addressed.

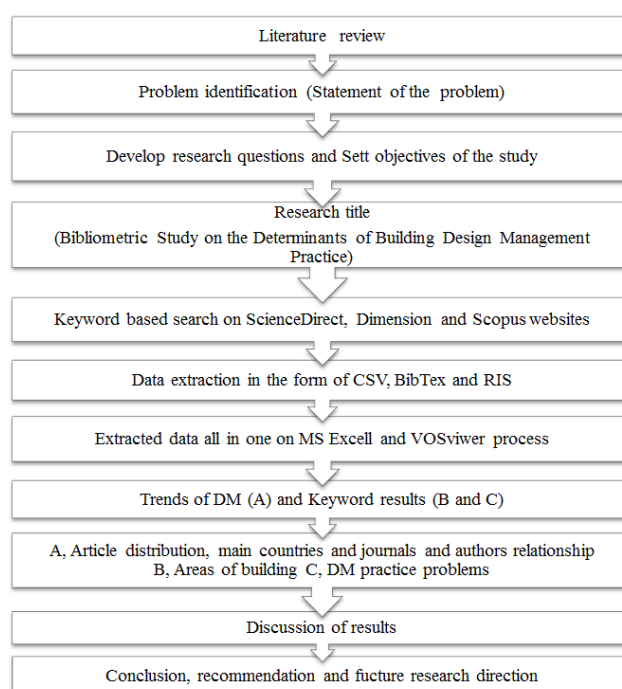


Figure 1. Research flow chart.

The study's population primarily consisted of published articles sourced from reputable databases such as Dimension, Scopus, and ScienceDirect, providing extensive coverage of Architecture, Engineering, and Construction (AEC) topics. Keyword-based searches were conducted, utilizing terms derived from the study's title, notably "building," "design," and "management." Articles were meticulously selected based on predefined criteria, with a focus on journals specializing in building construction, design management, and the AEC industry. This approach ensured the inclusion of pertinent literature for comprehensive analysis and interpretation.

During the data processing phase using VOSviewer software, irrelevant ideas unrelated to building design management were efficiently filtered out. The analysis employed two main bibliometric techniques: performance analysis, which assesses research contributions, and science mapping, which explores connections among research elements.

In conducting bibliometric analysis, researchers set a threshold value to determine the minimum number of items required for analysis. They could choose between two counting methods: full counting or fractional counting. Full counting assigns equal importance to each author of a publication, while fractional counting distributes the weight proportional-

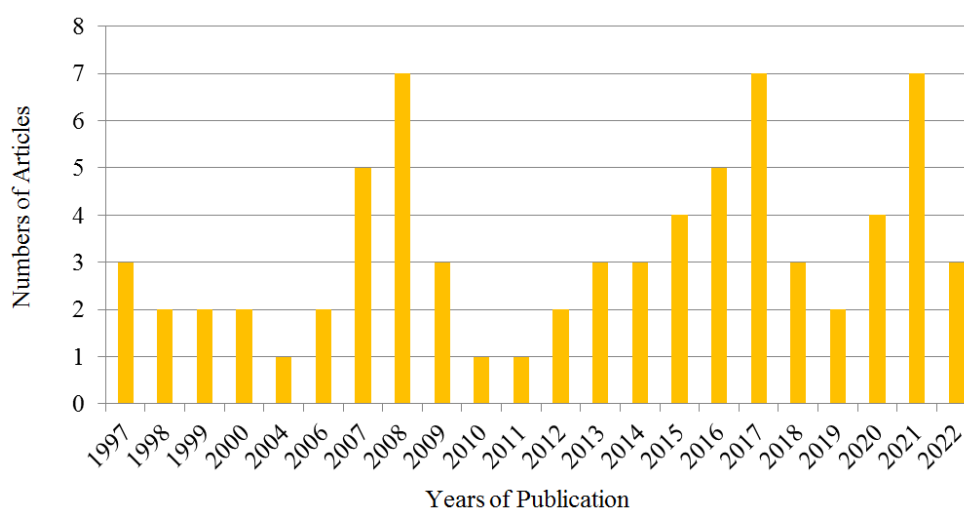
ly among authors, reflecting varying levels of contribution. This careful consideration of counting methods is crucial for ensuring the accuracy and relevance of the insights derived from the analysis, as it maintains fair recognition across publications and accurately represents the contributions of multiple authors [17].

### 3. Results and Discussions

#### 3.1. Growth Trends in Research on Building Design Management Studies

##### 3.1.1. Annual Distribution of Articles

A total of 72 articles on building design management and practice problems were selected for analysis between 1997 and 2022. Peaks in publication frequency occurred in 2008, 2017, and 2021, each year yielding seven articles. It's worth noting that articles published up to June 25, 2022, were included in the analysis.



**Figure 2.** Total number of relevant articles published between 1997 and 2022.

##### Main countries

The main countries contributing to the publications are the United Kingdom (9.7%), China (6.9%), Australia (4.17%), Norway (4.1%), the United States (2.7%), and Brazil (2.7%), totaling 30.3% of the publications. Additionally, India, Canada, Finland, Saudi Arabia, Egypt, and Portugal collectively contribute 8.3% of the publications. The remaining countries, not listed, account for 61.4% of the publications in this research paper.

##### 3.1.2. Main Journals

Table 1 presents the most productive journals, which col-

lectively contribute to 54.2% of all publications (39 out of 72) considered. The majority of these journals are interdisciplinary, indicating the integration of building design management principles across various Architecture, Engineering, and Construction (AEC) disciplines. In total, 26 journals were identified from the 72 articles, covering topics such as architectural engineering, design management, construction management, building engineering, civil engineering, energy and buildings, project management, building and environment, and other research fields.



**Table 1.** Journals have two or more articles.

Source (Journals)	Numbers of Articles
Construction Management and Economics	13
Architectural Engineering and Design Management	10
Automation in Construction	5
Building Research and Information	4
Energy and Buildings	3
Energy	2
International Journal of Project Management	2

### 3.1.3. Authors Relationship

Indeed, stronger linkages between authors signify more robust scientific collaboration, which is crucial for the continual professional growth of building design management. Collaboration among writers fosters the exchange of knowledge, ideas, and expertise, leading to innovative solutions and advancements in the field. By working together, authors can leverage their collective strengths to address complex challenges and drive progress in building design

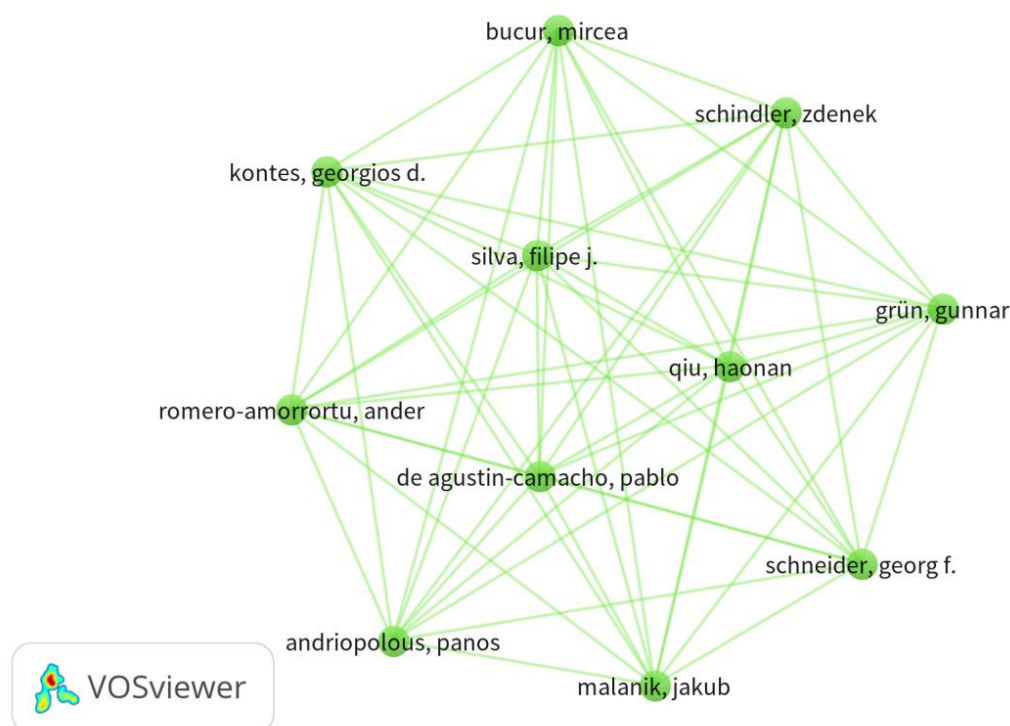
management. The co-authorship relationships between authors on building design management are the following:

#### A. ScienceDirect co-authorship analysis:

In the building design management conceptual foundational analysis, the maximum number of authors per document with a type of analysis co-authorship and a unit of analysis as authors was 25, according to the VOSviewer default analysis utilizing the full counting approach. Among the 100 authors included in the analysis, each author had a minimum of 1 and a maximum of 2 documents associated with them.

In Dimension's co-authorship analysis on design management, "Rounce, Geoff" stands out with 53 citations but zero link strength. Notably, authors like "Almeida, Manuela," "Engvall, Karin," and "Lampa, Erik" each garnered 27 citations, while "Casey, Colin" and "Hughes, Will" received 24 citations apiece. Some authors, including "Hansen, Geir K.," "Knotten, Vegard," and "Idre, Ola," secured 20 citations. Others had fewer citations, ranging from 4 to 0.

In the same analysis, focusing on design management, seven authors form the largest network. Among them, "Lappalainen, Eelon" leads, connecting with "Menzhinskii, Nikolai," "Peltokorpi, Antti," "Piitulainen, Mikko," "Pikas, Ergo," "Seppänen, Olli," and "Uusitalo, Petteri." Other authors displayed fewer connections, with links ranging from 4 to 0.

**Figure 3.** ScienceDirect maximum co-authors relationship on building design management.

#### B. Dimension co-authorship analysis:

In the VOSviewer default analysis, using a type of analy-

sis Co-authorship and a unit of analysis as authors, the maximum number of authors per document was 25. The mini-

imum number of documents associated with an author was one, and the minimum number of citations of an author was also one. Out of 42 authors considered, 36 met these thresholds, indicating their inclusion in the analysis.

In Dimension's co-authorship analysis, "Rounce, Geoff" leads with 53 citations but zero link strength. Authors like "Almeida, Manuela," "Engvall, Karin," and "Lampa, Erik" each have 27 citations, while "Casey, Colin" and "Hughes, Will" hold 24 citations each. Others, such as "Hansen, Geir K.," "Knotten, Vegard," and "Idre, Ola," received 20 cita-

tions. Meanwhile, some authors have fewer citations, ranging from 4 to none.

Within the realm of design management, Dimension's analysis highlights stronger author connections. The largest group, depicted in Figure 4, includes "Lappalainen, Eelon," "Menzhinskii, Nikolai," "Peltokorpi, Antti," "Piitulainen, Mikko," "Pikas, Ergo," "Seppänen, Olli," and "Uusitalo, Petteri," with one author linked to six others. Other authors have fewer connections, ranging from 4 to none.

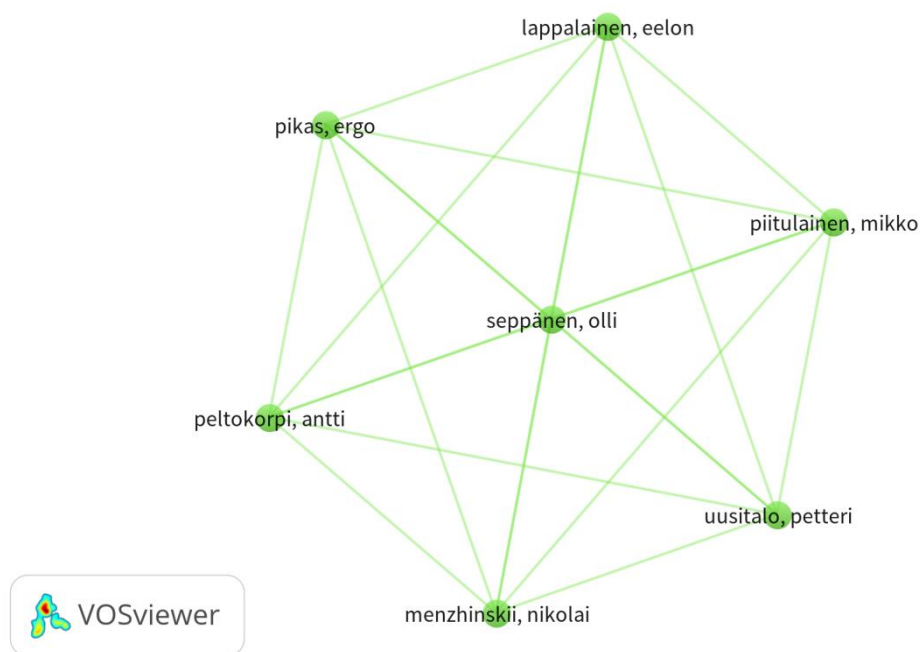


Figure 4. Dimension maximum co-authors relationship on building design management.

### C. Scopus co-authorship analysis:

Using co-authorship analysis, focusing on authors and employing full counting methods in VOSviewer's default settings, a total of 21 authors met the thresholds, each with at least 1 document and 0 citations.

## 3.2. Areas of Building Design Management Analysis

The analysis revealed a minimum occurrence of one keyword within the unit of analysis, totaling 109 keywords. The most pertinent keywords were identified, focusing on building design management areas and problems. Through systematic literature review, irrelevant keywords were removed, and remaining terms were systematically categorized into clusters with similar meanings.

Utilizing the full counting method, terms appearing at least twice in the title and abstract were considered. Out of 517 terms, 109 met this criterion, each assigned a relevancy score. The top 60% most relevant terms, totaling 65 sets,

were selected for further analysis. For terms appearing at least once in the title field, 19 terms were identified. A relevancy score determined the most pertinent terms, with the top 60% selected, constituting the core 11 keywords.

### 3.2.1. Cluster one Building Energy Management Result and Discussion

Understanding and implementing Nearly Zero Energy Building (nZEB) concepts is vital for meeting the Energy Performance of Buildings Directive (EPBD) goals. nZEB focuses on achieving high energy performance through renewable sources and integrating energy efficiency measures with renewable technologies. For technicians involved in building design, administration, and approval, understanding nZEB principles is crucial for ensuring compliance with energy efficiency and carbon reduction objectives. This includes knowledge of insulation, efficient HVAC systems, energy-efficient lighting, passive design strategies, and renewable energy integration. Integrating nZEB concepts can significantly reduce energy consumption and carbon emis-

sions, supporting climate change mitigation and sustainable development [18].

**Table 2.** Cluster one building energy management.

Cluster 1; Building Energy Management			
Website	Term(s)	Occurrence	Link strength
Science-Direct	Energy efficiency	3	11
	Active cool thermal energy storage	2	7
	Energy	1	6
	Energy consumption	1	6
	Energy informatics	1	6
	Energy use	1	6
	Thermal comfort	1	6
	Combined cooling heating and power (cchp)	1	5
	Electricity tracking (et)	1	5
	Energy island (ei)	1	5
	Equivalent ventilation area	1	5
	Heat tracking (ht)	1	5
	Hybrid ventilation	1	5
	Thermal performance	1	5
	Ventilation performance	1	5
	Cooling heating and power (chp)	1	4
	Coupling energy systems	1	4
	Energy management	1	4
	Energy metering	1	4
	Fuel cells	1	4
	Heat pumps	1	4
	Multi energy system	1	4
	Renewable energy sources	1	4
	Peak load management	1	4
	Climate change	1	3
	Eco-efficiency	1	3
	Intelligent building energy management system (ibems)	1	3
	Photovoltaic cells	1	3
	"building, ground heat exchanger"	1	2
	Thermal management	1	2
	Phase change material	1	2
Dimension	Term(s)	Occurrences	Relevance Score
	Space heating	3	1.1957
	Energy use	5	1.1806



**Cluster 1; Building Energy Management**

Website	Term(s)	Occurrence	Link strength
	Zero Energy Buildings (zeb) design process	5	1.1806
	Solar system	4	1.1151
	Energy	4	1.114
	Nearly Zero Energy Buildings (Nzeb)	7	1.0969

Commercial buildings equipped with active cool thermal energy storage (TES) and advanced HVAC systems can achieve substantial cost savings and operational benefits. These technologies effectively manage peak demand, reducing electricity costs associated with peak load management. By storing cool energy, these systems offer flexibility for demand response programs, enabling adjustments based on grid conditions or pricing signals. This enhances operational efficiency and supports grid stability by reducing strain during peak periods. Integrating active cool TES and advanced HVAC systems into commercial buildings optimizes energy management, lowers operational expenses, and contributes to a more resilient energy ecosystem [19].

Building envelope design is critical for a building's thermal efficiency, affecting energy usage and indoor comfort. Key factors, such as window area and performance, significantly influence the sensible cooling load. External shading can effectively reduce solar heat gain and lower cooling loads, while window insulation performance has a relatively minor impact. However, the overall thermal performance of windows, including U-value and solar heat gain coefficient (SHGC), still affects energy efficiency. An integrated approach to building envelope design, combining external shading strategies with window performance, is essential for optimizing energy use, enhancing indoor comfort, and minimizing cooling loads [20].

Designing for building exterior performance and durability requires addressing atmospheric moisture loading, which varies with climate and environmental factors. Historical moisture data may be insufficient due to climate change impacts on precipitation, humidity, and extreme weather. Designers should adopt a forward-thinking approach that includes projected climate changes and resilience measures. This involves using advanced moisture management strategies, durable materials, proper drainage systems, and adaptable designs. By proactively addressing moisture challenges, designers can enhance the long-term performance and durability of building exteriors in a changing environment [21].

Cogeneration (CHP) and heat pumps (HP) are increasingly essential in energy systems, especially for building renovation and industrial processes. CHP systems enhance efficiency by generating both heat and electricity from a single fuel source, resulting in significant energy savings and reduced

emissions. They are particularly valuable for meeting heating and power needs in buildings and industrial facilities. Similarly, heat pumps, utilizing renewable sources like air, water, or the ground, provide efficient heating, cooling, and hot water with environmental benefits. Integrating CHP and heat pump technologies improves efficiency, reduces greenhouse gas emissions, and enhances energy security. As the shift towards sustainable energy systems progresses, the role of CHP and heat pumps in driving efficiency and decarbonization will remain crucial [22].

Multi-energy systems, which integrate electricity, heat, and hydrogen, are crucial for transitioning to decentralized, low-carbon energy systems. These systems optimize energy use, enhance flexibility, and increase resilience. Hydrogen, as a versatile energy carrier, has potential applications in transportation, industry, and power generation, particularly when produced from renewable sources via electrolysis. In a multi-energy system, these interconnected energy vectors are managed to maximize efficiency and minimize environmental impact. Embracing integrated approaches like these can accelerate the shift towards a more sustainable and resilient energy future [23].

Energy Informatics integrates energy data with information technology to reduce consumption, encapsulated by the principle "Energy + Information = Less Energy." In building operations, Facilities Management and Modeling (FMM) systems are crucial for enhancing energy efficiency, based on three core principles: measurement, modeling, and management. Measurement involves collecting real-time energy use data. Modeling uses this data to create predictive simulations for optimizing consumption. Management applies strategies from these insights to improve operations and reduce waste. By integrating these principles, FMM systems are vital for achieving energy efficiency in building management [24].

Evaluating a building energy management model involves three key metrics: complexity, usability, and design. Complexity measures the model's balance between sophistication and simplicity. Usability assesses how easily users can understand and operate the model. Design focuses on the model's architecture and coherence. Addressing these metrics ensures the development of high-quality, reusable models that enhance energy efficiency and performance in buildings [25].

The primary concerns in building energy management are reducing energy consumption and achieving thermal comfort. Reducing energy use involves minimizing the energy needed for heating, cooling, lighting, and other operations, which lowers environmental impact and costs. Ensuring thermal comfort requires effective insulation, efficient HVAC sys-

tems, and proper ventilation to maintain comfortable indoor temperatures year-round. Balancing these objectives necessitates a holistic approach that integrates energy efficiency with occupant comfort, promoting sustainable and resilient built environments [26].

### 3.2.2. Cluster Two Building Type and Users Result and Discussion

*Table 3. Cluster two building type and users.*

Cluster 2; Building Type and Users			
Website	Term(s)	Occurrence	Link strength
Science-Direct	Buildings	1	6
	Household and personal factors	1	6
	Occupants behavior	1	6
	Residential buildings	1	6
	Building envelopes	1	5
	Building and industrial applications	1	4
	Occupant comfort	1	4
	Demand response	1	4
	Smart building management system	1	4
	Term(s)	Occurrences	Relevance Score
Dimension	Dwelling	2	1.2037
	Complex building project	2	1.1203
	New building	2	1.1203
	Home	2	0.9211
	Apartment	2	0.8861
Scopus	Household	5	0.7831
	Term(s)	Occurrences	Relevance Score
	High performance building project	1	1.76

Occupants of smart buildings benefit from advanced management systems that enhance efficiency, safety, and comfort. These systems use cutting-edge technology to optimize heating, ventilation, air conditioning, lighting, and security. By integrating sensors, actuators, and data analytics, smart buildings adjust settings in real-time based on occupancy, weather, and energy demand, leading to energy savings and reduced operational costs. Safety is improved with automated emergency responses and real-time monitoring, while comfort is enhanced through personalized settings for temperature, lighting, and air quality. Effective design, implementation, and maintenance are crucial for ensuring seamless

technology integration, data privacy, and user-friendly interfaces. Prioritizing these aspects allows smart buildings to offer superior occupant experiences and maximize energy efficiency and sustainability [27].

Several factors significantly impact heating energy use in buildings. Building age and type are crucial, as older structures typically have poorer insulation and lower energy efficiency. The design of the ventilation system also matters; inadequate ventilation can lead to heat loss or inefficient air distribution. The time since the last heating adjustment affects energy use, with outdated or manual controls potentially causing unnecessary heating during low-occupancy peri-

ods or warmer weather. Ownership type influences energy efficiency through varying investment levels in energy-efficient technologies and maintenance. Additionally, demographic factors, such as the percentage of females and residents reporting thermal discomfort, can impact heating energy consumption. Addressing these factors is essential for optimizing heating energy use and improving overall energy efficiency [28].

Building trust within teams is essential for optimal performance and collaboration. When team members trust each other, they are more likely to share ideas openly and work together effectively. This mutual respect and safety foster innovation and enable teams to overcome challenges more successfully. Trust enhances individual satisfaction, improves team dynamics, and boosts overall productivity [29].

### 3.2.3. Cluster Three Building Information Modeling and Management Result and Discussion

**Table 4.** Cluster three building information modeling and management.

Cluster 3: BIM and Information Management			
Website	Term(s)	Occurrence	Link strength
Science-Direct	Information systems	1	6
	Building information modeling (bim)	1	5
	Digital programming	1	5
	Model-based control	1	4
	Multidimensional model	1	4
	Petri nets model	1	4
	Simulation	1	4
	Bim	1	3
	Bim-based refurbishment	1	3
	Building data model	1	3
	Component-based cad	1	3
	Floor plan representation	1	3
	Numerical simulations	1	3
Dimension	Term(s)	Occurrences	Relevance Score
	Software	2	1.0292
	Bim	4	0.9945
	Model	5	0.9945
	Information flow	6	0.9039

An intelligent architecture CAD system is essential for managing spatial and formal information effectively, ensuring accurate design representation. Automation tools such as parametric modeling and generative design expedite floor plan creation and allow for rapid design iterations. Real-time construction management features enhance collaboration between design and construction teams, addressing issues promptly and improving coordination. By integrating these capabilities, the CAD system streamlines the design process, fosters collaboration, and ensures a smooth transition from

project conception to realization [30].

The analytical framework for BIM-based design and renovation offers a robust method for evaluating building energy consumption and eco-building factors. By using pre-built indicators, it simplifies the assessment of energy efficiency and environmental performance. This framework integrates optimization subsystems within BIM for ongoing improvement of renovation processes. It considers multiple criteria, including energy efficiency, eco-efficiency, and economic factors, ensuring decisions account for environmental impact,

financial viability, and sustainability. Applying these principles helps stakeholders make informed choices that enhance building performance, reduce energy consumption, and support eco-friendly practices throughout design and renovation [31].

Integrating BIM applications into building operations creates a continuous feedback loop that enhances the design process. This approach ensures that buildings perform well in practice, not just in theory. Real-time data from BIM allows for timely adjustments and improvements, addressing issues before they become significant and ensuring performance expectations are met throughout the building's life cycle. This iterative evaluation supports more sustainable and effective building management [32].

Leveraging information-constrained Petri nets for resource management in building design enhances efficiency by enabling simulation and optimization of resource allocation strategies. This approach reduces development cycle times by managing resource utilization logically throughout the design process. Information-constrained Petri nets address both theoretical and practical aspects, offering a structured framework for real-time decision-making and optimization.

This sophisticated toolset improves efficiency and streamlines processes in contemporary building design management [33].

Petri nets are a vital graphical modeling tool in software development, clarifying complex systems and processes. They reveal logical relationships among activities, aiding in the identification of information flow, resource management, and potential inefficiencies. Using Petri nets allows developers to create detailed design models that support in-depth analysis and iterative refinement, enhancing communication and streamlining the development process [34].

In design management, ensuring the seamless flow of accurate information between design partners is crucial, and Building Information Modeling (BIM) is key to this process. BIM provides a centralized platform for sharing and accessing design data among all stakeholders. It enables prompt and comprehensive distribution of outputs, ensuring that collaborators have the necessary information for informed decision-making and effective collaboration. This integration streamlines the design process, reduces errors, and enhances overall project success [35].

### 3.2.4. Cluster Four Design Management Service Result and Discussion

*Table 5. Cluster four design management services.*

Cluster 4; Design Management Service			
Website	Term(s)	Occurrence	Link strength
Science-Direct	Building demand management	2	7
	Building management service	1	4
	Design management	1	4
	Design optimization	1	4
	Design building	1	3
	Building design management	1	2
	Term(s)	Occurrences	Relevance Score
Dimension	Bdm success factor	6	0.9715
	Factor	5	0.9448
	Design management system	3	1.0319
	Key success factor	3	1.0135
	Design participant	3	1.0112
	Building design process	2	0.7939
	Process	16	0.5662
	Design phase	2	1.0281
	Participant	3	1.0112
	Design team	2	0.7868

Cluster 4; Design Management Service			
Website	Term(s)	Occurrence	Link strength
	Term(s)	Occurrences	Relevance Score
Scopus	Building design management	2	1.76
	Key success factor	1	1.76
	Team	1	1.76
	Construction design manager	1	0.66

The building design process varies in complexity, from simple structures to extensive multistory buildings. Effective management hinges on high levels of collaboration among diverse teams, integrating expertise to meet client objectives efficiently and cost-effectively. By leveraging team strengths and fostering coordination, design management streamlines workflows, enhances communication, and delivers high-quality outcomes within budget and time constraints, ensuring client satisfaction and project success [35].

The architecture, engineering, and construction sectors are greatly influenced by the drive for improved quality and productivity. Many challenges emerge early in the project design phase, underscoring the importance of effective build-

ing design management. Streamlining processes, enhancing collaboration, and optimizing resource allocation are essential to address these challenges. Effective design management ensures seamless coordination among multidisciplinary teams and fosters innovative solutions. Prioritizing efficient design management practices helps stakeholders overcome obstacles, unlock opportunities, and achieve superior project outcomes that exceed client expectations [36].

Forming a multidisciplinary design team early in the project is crucial. This group collaborates to refine the design, leveraging diverse expertise to optimize outcomes through creative problem-solving and regular communication [37].

### 3.2.5. Cluster Five Project Management Result and Discussion

*Table 6. Cluster five project management.*

Cluster 5; Project Management			
Website	Term(s)	Occurrence	Link strength
Science-Direct	Resource management	1	4
	Construction management	1	3
	Facilities management	1	3
	Demand management	1	3
	Term(s)	Occurrences	Relevance Score
Dimension	Procurement Process	2	1.1475
	Project Management	2	0.774

This statement highlights a common issue in project delivery, where facilities management (FM) concerns are often inadequately addressed. This oversight results in information gaps between FM requirements and the project design due to insufficient communication or collaboration between design teams and FM stakeholders in the early phases. Consequent-

ly, critical FM considerations like maintenance, operation, and life cycle management may be overlooked, leading to inefficiencies, increased costs, and operational challenges after project completion. To address these gaps, it is crucial for design and FM teams to engage proactively throughout the project life cycle, integrating FM requirements into the



design from the start [32].

Recent advancements in information and communication technologies have greatly facilitated the formation of international design teams, streamlining the global procurement of architecture, engineering, and construction services. Engaging multinational design firms for complex projects in developing countries offers significant benefits, including technology transfer and the adoption of innovative architectural and engineering methodologies [38].

The architect criticized the design management for its unclear lines of responsibility. While the project management and construction teams had well-defined coordinating roles, the construction team assumed traditional design manager duties. These responsibilities included controlling, registering, distributing, and issuing design documents, as well as managing quality and changes, using a spreadsheet they developed to guide the architect [38].

### 3.2.6. Cluster Six Sustainable Design and Value Engineering Result and Discussion

*Table 7. Cluster six sustainable design and value engineering.*

Cluster 6; Sustainable design and Value engineering			
Website	Term(s)	Occurrence	Link strength
Science-Direct	Sustainable building	1	3
	Sustainable target value (stv)	1	3
	Life cycle assessment (lca)	1	3
	Life-cycle cost saving	1	3
	Sustainable urban drainage.	1	2
	Rainwater management	1	2
Dimension	Term(s)	Occurrences	Relevance Score
	Sustainable built environments	3	2.3752
	Sustainable school building	2	1.3206
	Waste management	2	0.9211
	Wastage	2	0.7982
	Term(s)	Occurrences	Relevance Score
Scopus	Delivering sustainable building	1	0.66
	Sustainable urban development design management	1	0.66

Efficient rainwater utilization can achieve substantial water savings, potentially reducing consumption by around 50% for activities such as toilet flushing, laundry, plant watering, and cleaning. Urban drainage systems face significant environmental challenges, necessitating the development of economically viable and politically acceptable advancements in sustainable building design [39].

The Sustainable Target Value (STV) methodology integrates Life Cycle Assessment (LCA) with Target Value Design (TVD) to advance eco-friendly building designs. Combining LCA's environmental impact evaluation with TVD's focus on budget constraints, STV helps project teams efficiently identify and prioritize sustainable design strategies. This approach promotes informed decision-making and stakeholder collaboration, ensuring buildings are both envi-

ronmentally responsible and cost-effective [40].

The construction design manager is crucial to the success of sustainable building projects. They define team roles and develop a detailed plan to implement sustainable practices throughout the project life cycle. This involves coordinating with architects, engineers, contractors, and other stakeholders to integrate sustainable design principles, materials, and technologies. The manager oversees the sustainability plan's execution, monitors progress, and addresses challenges, ensuring the project efficiently and effectively meets its sustainability goals [41].

Building design management faces evolving challenges due to rising project complexity and expert specialization. Clients now focus on long-term costs and value for money in addition to initial expenses. Architects must balance com-

mercial interests with essential design considerations. In addressing practical needs in small apartments, such as waste management and storage, they may overlook opportunities

for advancing societal norms and waste infrastructure management [42].

### 3.3. Building Design Management Practice Problem Result and Discussions

**Table 8.** Building design management practice problems.

Website	Problem	Occurrence	Relative Strength
Science-Direct	Building operations	1	6
	Building fabric maintenance	1	5
	Cost and schedule planning	1	5
	Integrated assessment	1	5
	Integration	1	5
	Building operational costs	1	4
	Information constraint net	1	4
	Design costs	1	4
	Efficiency	1	4
	Quality	1	4
	Knowledge-based decision-making	1	3
	Building performance	1	3
	Spatial information	1	3
Dimension	Problem	Occurrences	Relevance score
	Integration	3	1.1559
	Communication technology	2	1.1203
	Employment	2	1.123
	International design team	2	1.1203
	Design quality problem	2	1.0726
	Low trust level	2	1.0726
	Association	2	1.0726
	Dqp (design quality Problem)	4	1.0608
	Trust	7	1.0446
	Collaboration	2	0.768
	Communication	4	0.5572
	Responsibility	2	0.7273
Scopus	Problem	Occurrences	Relevance score
	Fragmented regulatory environment	1	0.66
	Role identification	1	0.66

Traditional CAD systems, which focus primarily on graphic data, often lead to design inconsistencies and exces-

sive modifications. Adopting standardized formats like the IFC (Industry Foundation Classes) model is essential to ad-

dress these issues. Standardization enhances interoperability, streamlines data exchange across software platforms, and improves consistency and efficiency in the design process [31].

An innovation management workflow that integrates Building Information Modeling (BIM) with digital programming optimizes building maintenance planning. This integration leverages BIM's detailed data and digital programming's computational power for schedule simulations and cost estimations. By streamlining the planning process, stakeholders can better anticipate maintenance needs, make informed scheduling and budgeting decisions, and enhance overall efficiency, reducing costs and ensuring effective long-term asset management [43].

Incorporating Building Information Modeling (BIM) into the building operation phase is crucial for evaluating performance during occupancy. It offers real-time data on energy consumption, occupant behavior, and environmental conditions, enabling designers to address performance issues early and refine strategies. This proactive approach enhances building performance, improves occupant comfort, and supports sustainability efforts [32].

Applying quality management techniques to architectural design, while integrating concepts of waste, quality, and efficiency, is essential but novel. Despite the challenges in measuring these complex elements, the increasing focus on sustainability and resource optimization necessitates developing effective frameworks and tools. Innovative methodologies can help architects minimize waste, enhance quality, and optimize efficiency, leading to more sustainable and resilient built environments [44].

Trust is fundamental for fostering cooperation and building high-performance teams. It relies on members' dependence on each other's expertise and collaborative efforts towards shared goals. Key factors influencing trust include initial seminars, team composition, shared interests, management support, cooperative problem-solving, and integrated concurrent engineering. These elements affect team experiences, problem-solving capabilities, goal alignment, reciprocity, and behavior, all of which support the development and maintenance of trust [29].

In underdeveloped nations, involving foreign design firms in complex construction projects can offer benefits like technology transfer and innovative design ideas. However, it also presents risks, including linguistic, administrative, organizational, and cultural barriers. These challenges, exacerbated by limited personal connections and slow adoption of communication tools, can complicate design and construction phases. Proactively addressing these issues is crucial for successful project execution and effective cross-border collaboration [38].

Regulatory fragmentation and extensive consultations have led stakeholders to use various persuasion strategies, notably "reciprocity" and "authority." Design managers face two main challenges: establishing themselves as central in-

formal arbitrators among competing planning instruments and effectively navigating diverse persuasion techniques to manage stakeholders and achieve project success [45].

The proposed method for real-time scheduling issues in workflow management systems uses a p-time Petri net model with hybrid resources. Petri nets are graphical tools that illustrate the flow of activities and resources. The "p-time" variant incorporates time constraints for real-time scheduling, while hybrid resources combine various resource types, such as human workers and automated tools. This approach effectively manages scheduling challenges by modeling activity flow, resource use, and time constraints, optimizing efficiency and ensuring timely task completion (Cheng et al., 2013). Limited research has delved into the connections among trust, information flow, and design quality problems (DQP), or their interactions. However, studies in lean design management emphasize the critical role of managing information flow effectively [46].

Effective management of design teams hinges on excellent communication and control over their workflows. In this context, a simulation model is outlined, specifically focusing on activities during the idea and schematic design stages. This model utilizes discipline-based information flow models to map out the building design process [47].

The most critical issues in design team interactions revolve around role identification, communication, collaboration, coordination, and trust. These elements are pivotal for ensuring effective teamwork and successful project outcomes [48].

According to the results, [table 9](#) shows a proposed solution for each problem.

**Table 9.** Design management practice problems with corresponding solution.

Problems	Solution with its reference
Scheduling problems	Petri net model [45]
Spatial information	IFC (Industry Foundation Classes) model [47]
Building operation	BIM applications [48]
Information flow	Lean design management [16]
Week team performance	Develop trust on team [29]

## 4. Summary on a Results of the Study

Trends in building design management studies reveal significant patterns in the field's evolution and research distribution. Notable peaks in publication years, such as 2008, 2017, and 2021, highlight major contributions from countries like the United Kingdom and China, reflecting global interest. Publications are widespread, indicating broad international

engagement, with key journals including Construction Management and Economics and Architectural Engineering and Design Management playing prominent roles. While author relationships vary and are not explicitly shown on all platforms, comprehensive coverage is available through sources like Scopus. These trends emphasize a global interest in building design management, supported by diverse publication outlets and international contributions.

The six determinant areas of building design management encompass a comprehensive range of factors crucial for successful design and implementation. These clusters address critical aspects such as energy management, building types, information modeling, design services, project management, and sustainable design. Each cluster delves into specific facets, reflecting the multidisciplinary nature of the field, from energy efficiency to sustainable development practices.

On the other hand, prevalent challenges in building design management practice are encapsulated in six categories, including integration and collaboration problems, operational and maintenance issues, communication difficulties, design quality concerns, diminished trust levels, and role ambiguity. Addressing these challenges requires proactive management, robust communication channels, clear role definitions, and a collaborative approach among all project stakeholders. By implementing effective strategies, organizations can navigate these challenges and enhance project outcomes effectively.

#### *Study Finding Implications*

Based on the study's thorough examination of building design management practices, several key recommendations have been proposed to address significant challenges within the field. Firstly, in terms of information management, it is suggested that regulatory bodies mandate the inclusion of crucial concepts such as Building Information Modeling (BIM), Industry Foundation Classes (IFC), and the Petri Net model in procurement and contract bidding processes. This regulatory enforcement would ensure widespread adoption of advanced tools and standards, enhancing project coordination and data management efficiency.

Secondly, within project management, appointing a dedicated design manager, under the supervision of a project manager, emerges as a vital strategy. This designated role would oversee the intricacies of the design process, elevating design quality while ensuring adherence to project timelines and budgets.

Furthermore, addressing role and responsibility identification issues requires proactive measures. Design managers should prioritize allocating clear roles and responsibilities within design teams to foster cohesion and streamline project execution. Additionally, fostering trust and collaboration among team members is essential for cultivating a high-performing team environment conducive to successful project outcomes.

In conclusion, implementing these recommendations is crucial for improving processes, enhancing collaboration, and overcoming challenges in building design management.

Organizations that adopt these guidelines can navigate complexities more effectively, leading to improved project outcomes and stakeholder satisfaction.

## 5. Conclusion

Based on the identified trends, research in building design management is still evolving, with significant opportunities for further development. The modest annual publication volume suggests ample potential for exploration and refinement in this field. Contributions from the United Kingdom and China highlight global interest, but increased involvement from other countries is necessary for a more comprehensive understanding of design management practices. The concentration of research in certain journals underscores the need for a broader range of publication venues to capture diverse perspectives and methodologies. Additionally, the limited author interconnections present an opportunity to enhance collaboration and knowledge exchange, which could improve the quality of design practices.

Moving forward, the identified determinant areas of building design management cover a comprehensive array of factors pivotal for effective project delivery and sustainable results. Building Energy Management focuses on optimizing energy efficiency and consumption, including the integration of renewable energy sources, with an aim to achieve net-zero energy building design, thereby minimizing environmental impact. Building Type and Users considers the unique needs and characteristics of various building types, emphasizing user comfort and satisfaction to enhance building usability and functionality. Building Information Modeling and Management utilizes information systems and modeling tools to streamline project management processes and highlights the integration of digital technologies for enhanced collaboration among stakeholders. Design Management Services develop strategies and frameworks for efficient design management, addressing factors influencing design success. Project Management encompasses resource management, demand forecasting, and procurement management to ensure project success. Sustainable Design and Value Engineering promotes environmentally sustainable building practices and considers life cycle cost-saving measures. By focusing on these determinant areas, building design management can effectively address key challenges and opportunities within the construction industry, leading to more resilient, efficient, and sustainable built environments.

Lastly, the study aims to investigate major building design management practice problems, with a focus on integration and collaboration, operational and maintenance issues, information and communication challenges, design quality and efficiency concerns, reduced trust levels, and role and responsibility identification problems. These challenges encompass difficulties in coordinating different design aspects, ensuring long-term building functionality, sharing project information effectively, maintaining high design standards

within project constraints, fostering trust among stakeholders, and clarifying roles and responsibilities. Addressing these challenges necessitates clear communication channels, collaborative efforts, robust project management practices, and a commitment to transparency and accountability. By tackling these issues proactively, organizations can enhance project outcomes and meet stakeholders' expectations more effectively.

#### Future Research Directions

The researchers provided guidance for future research in the following areas, which are derived from the study's findings:

- 1) **Exploration of Under-Researched Areas:** Future research endeavors should delve into overlooked aspects of building design management. Exploring emerging trends, innovative practices, and niche topics within the field will contribute to a deeper understanding and advancement of building design management methodologies.
- 2) **Global Comparative Analysis:** There is a pressing need for comprehensive comparative analyses of building design management practices across diverse geographical regions. Such studies would offer critical insights into how cultural, regulatory, and contextual factors influence design management approaches globally, enhancing our ability to develop universally applicable best practices.
- 3) **Diversification of Publication Venues:** Efforts to broaden the dissemination of research findings beyond traditional journals are essential. Exploring alternative outlets such as interdisciplinary publications and industry platforms will facilitate the exchange of knowledge and promote the adoption of innovative building design management strategies.
- 4) **Promotion of Collaboration and Knowledge Exchange:** Initiatives aimed at fostering collaboration and knowledge exchange among researchers are paramount in advancing building design management. Establishing interdisciplinary forums, collaborative research projects, and networking opportunities will facilitate the sharing of best practices and drive innovation within the field.
- 5) **Advanced Building Design Management Practices:** Future research should focus on exploring cutting-edge technologies, methodologies, and strategies specific to building design management. By emphasizing areas such as sustainable design principles, digital transformation, integrated project delivery methods, and lean construction practices, researchers can drive efficiency and excellence in building design processes.
- 6) **Addressing Key Challenges:** It is imperative for future research to address the significant challenges facing building design management practices. Investigating issues such as integration and collaboration challenges, operational efficiency, communication barriers, design quality assurance, stakeholder trust-building, and role clarification within design teams will provide actiona-

ble insights to improve project outcomes and enhance overall project success rates.

By embracing these refined future study directions, the scholarly community can catalyze progress in building design management, leading to more effective and sustainable built environments.

## Abbreviations

ADePT	Analytical Design Planning Technique
AEC	Architecture, Engineering, and Construction
AIA	American Institute of Architects
BIM	Building Information Modeling
BEMS	Building Energy Management Systems
CAD	Computer-Aided Drafting
CDCM	Construction Design Change Management
CSV	Comma Separated Values
DM	Design Management
FMM	Facilities Management and Modeling
HVAC	Heating, Ventilation, and Air Conditioning
HSF	Health and Safety Focus
IBEMS	Intelligent Building Energy Management System
LCA	Life Cycle Assessment
IFC	Industry Foundation Class
NZEB	Nearly Zero Energy Building
PM	Project Management
RIS	Research Information System
VDC	Virtual Design and Construction
VOSviewer	Visualization of Similarities Viewer

## Author Contributions

**Adamu Ajahunegn Agegn:** Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software and Visualization and Writing – original draft

**Meseret Getnet Meharie:** Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing

**Getahun Fetene Dinku:** Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing

## Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data include references to relevant literature and materials used in the research, as detailed in the manuscript's references section. For access to supplementary materials or additional information related to the study, please contact the corresponding author.



## Conflicts of Interest

The authors declare no conflicts of interest.

## References

- [1] Paz, D. H. F., Lafayette, K. P. V., & Sobral, M. C. M. (2020). Management of construction and demolition waste using GIS tools. Woodhead Publishing.
- [2] Adinew, B. T. (2020). Design management using building information modeling: In case of projects in Addis Ababa. Addis Ababa Institute of Technology, School of Civil and Environmental Engineering. Repository link: Addis Ababa University.
- [3] Knotten, V., Svalestuen, F., Hansen, G. K., & Lædre, O. (2015). Design management in the building process: A review of current literature. *Procedia Economics and Finance*, 21, 55-63. [https://doi.org/10.1016/S2212-5671\(15\)00155-2](https://doi.org/10.1016/S2212-5671(15)00155-2)
- [4] Knotten, V. (2017). Building design management in the early stages. Norwegian University of Science and Technology, Trondheim. Repository link: NTNU Open.
- [5] Emmitt, S. (2010). Design management in architecture, engineering and construction: Origins. *Architectural Engineering and Design Management*, 5(4), 345-356. <https://doi.org/10.3763/aedm.2010.0014>
- [6] Tzortzopoulos, P., & Cooper, R. (2007). Design management from a contractor's perspective: The need for clarity. *Architectural Engineering and Design Management*, 3(1), 1-12. <https://doi.org/10.1080/17452007.2007.9687053>
- [7] Bibby, L. (2003). Improving design management techniques in construction. Department of Civil & Building Engineering, Leicestershire.
- [8] Andersen, J., Nycyk, M., Jolly, L., & Radcliffe, D. (2005). Design management in a construction company. Catalyst Research Centre for Society and Technology, University of Queensland.
- [9] Whyte, J., & Tombesi, P. (2013). Challenges of design management in construction. Proceedings of the CIB World Building Congress, Sydney, Australia.
- [10] Whang, S. W. (2017). The influence of design-production management at the pre-production stage for major international projects in Korea. School of Construction Management and Engineering, University of Reading.
- [11] Hochschule Luzern. (2016). The role of design management. Lucerne School of Art and Design.
- [12] Ambachew, S. (2018). Assessment on design management practices of national consultants focused on building design projects. Addis Ababa Institute of Technology. DOI: [Unavailable - Repository link recommended].
- [13] Fadamiro, J. A., & Bobadoye, S. (2007). Managing the building design process for sustainability and improved quality. *Civil Engineering Dimension*, 8(2), 100-110. <https://doi.org/10.9743/ced.2007.06>
- [14] Knotten, V., Svalestuen, F., Hansen, G. K., & Lædre, O. (2015). Design management in the building process: A review of current literature. In 8th Nordic Conference on Construction Economics and Organization, France (pp. 120-127).
- [15] Koskela, L., Ballard, G., & Lauri, K. (1998). On the agenda of design management research. In Proceedings IGLC '98.
- [16] Hughes, C. G., & Gray, W. (2001). Building design management. Department of Construction Management & Engineering, University of Reading.
- [17] Perianes-Rodriguez, A., Ruiz-Castillo, J., & Costas, R. (2016). Constructing bibliometric networks: A comparison between full and fractional counting. *Journal of Informetrics*, 10(4), 1042-1054. <https://doi.org/10.1016/j.joi.2016.08.002>
- [18] Silva, S. M., Mateus, R., Ramos, M., & Almeida, M. (2016). Contribution of the solar systems to the NZEB and ZEB design concept in Portugal – Energy, economics and environmental life-cycle analysis. *Solar Energy Materials and Solar Cells*, 155, 371-382. <https://doi.org/10.1016/j.solmat.2016.05.027>
- [19] Cui, B., Gao, D. C., Xiao, F., & Wang, S. (2017). Model-based optimal design of active cool thermal energy storage for maximal life-cycle cost saving from demand management in commercial buildings. *Energy*, 201, 1-11. <https://doi.org/10.1016/j.energy.2017.05.071>
- [20] Hwang, R.-L., Huang, A.-W., & Chen, W.-A. (2021). Considerations on envelope design criteria for hybrid ventilation thermal management of school buildings in hot-humid climates. *Building and Environment*, 7, 2352-2360. <https://doi.org/10.1016/j.buildenv.2021.107280>
- [21] Jeong, D. I., & Cannon, A. J. (2020). Projected changes to moisture loads for design and management of building exteriors over Canada. *Building and Environment*, 160, 1-14. <https://doi.org/10.1016/j.buildenv.2019.106147>
- [22] Lo Basso, G., Nastasi, B., Salata, F., & Golasi, I. (2017). Energy retrofitting of residential buildings—How to couple combined heat and power (CHP) and heat pump (HP) for thermal management and off-design operation. *Energy and Buildings*, 151, 197-208. <https://doi.org/10.1016/j.enbuild.2017.07.053>
- [23] Bartolucci, L., Cordiner, S., Mulone, V., Pasquale, S., & Sbarra, A. (2022). Design and management strategies for low emission building-scale multi-energy systems. *Energy*, 239, 1-11. <https://doi.org/10.1016/j.energy.2021.121870>
- [24] Lawrence, T. M., Watson, R. T., Boudreau, M.-C., Johnsen, K., Perry, J., & Ding, L. (2012). A new paradigm for the design and management of building systems. *Energy*, 51, 1-12. <https://doi.org/10.1016/j.energy.2012.01.017>
- [25] Cavalheiro, J., & Carreira, P. (2016). A multidimensional data model design for building energy management. *Advanced Engineering Informatics*, 30(1), 23-35. <https://doi.org/10.1016/j.aei.2015.09.001>
- [26] Alwetaishi, G. M. (2018). Toward sustainable school building design: A case study in hot and humid climate. *Cogent Engineering*, 5, 1-12. <https://doi.org/10.1080/23311916.2018.1485035>

- [27] Eini, R., Linkous, L., Zohrabi, N., & Abdelwahed, S. (2021). Smart building management system: Performance specifications and design requirements. *Journal of Building Engineering*, 39, 1-11. <https://doi.org/10.1016/j.jobbe.2021.102264>
- [28] Engvall, K., Lampa, E., Levin, P., Wickman, P., & Öfverholm, E. (2014). Interaction between building design, management, household and individual factors in relation to energy use for space heating in apartment buildings. *Energy*, 81, 1-12. <https://doi.org/10.1016/j.energy.2014.02.058>
- [29] Engebo, A., Klakegg, O. J., Lohne, J., Bohne, R. A., Fyhn, H. B., & Laedre, O. (2020). High-performance building projects: How to build trust in the team. *Architectural Engineering and Design Management*, 16(1), 1-14. <https://doi.org/10.1080/17452007.2020.1712649>
- [30] Ustinovichius, L., Popov, V., Cepurnaite, J., Vilutienė, T., Samofalov, M., & Miedzialowski, C. (2018). BIM-based process management model for building design and refurbishment. *Journal of Civil Engineering and Management*, 24(3), 187-198. <https://doi.org/10.3846/jcem.2018.5256>
- [31] Choi, J. W., Kwon, D. Y., Hwang, J. E., & Lertlakkhanakul, J. (2007). Real-time management of spatial information of design: A space-based floor plan representation of buildings. *Automation in Construction*, 16(6), 789-799. <https://doi.org/10.1016/j.autcon.2006.12.009>
- [32] Oti, A. H., Kurul, E., Cheung, F., & Tah, J. H. M. (2016). A framework for the utilization of building management system data in building information models for building design. *Automation in Construction*, 72, 144-156. <https://doi.org/10.1016/j.autcon.2016.08.007>
- [33] Cheng, F., Li, H., Wang, Y.-W., Skitmore, M., & Forsythe, P. (2013). Modeling resource management in the building design process by information constraint Petri nets. *Automation in Construction*, 29, 111-121. <https://doi.org/10.1016/j.autcon.2012.08.015>
- [34] Ding, W. (2011). The development of architectural design management system based on Petri nets. In *Education Management, Education Theory and Education Application* (pp. 1-12). ISBN 978-3-642-24772-9.
- [35] Kassem, A. T. (2018). A framework for building design management in an imperfect BIM environment. *Engineering Management Research*, 7(1), 1-12. <https://doi.org/10.5539/emr.v7n1p1>
- [36] Knotten, V., Laedre, O., & Hassan, G. K. (2017). Building design management key success factors. *Architectural Engineering and Design Management*, 13(2), 139-151. <https://doi.org/10.1080/17452007.2017.1313121>
- [37] Giuliani, I., Aston, W., & Stewart, A. (2016). The design and development of an adaptable modular sustainable commercial building (CO<sub>2</sub>Nserve) for multiple applications. *International Journal of Ventilation*, 8(1), 1-12. <https://doi.org/10.1080/14733315.2016.1190604>
- [38] Grilo, L., Melhado, S., Silva, S. A. R., Edwards, P., & Hardcastle, C. (2011). International building design management and project performance: Case study in São Paulo, Brazil. *Architectural Engineering and Design Management*, 7(3), 211-225. <https://doi.org/10.1080/17452007.2011.625490>
- [39] Zelenakova, M., Markovic, G., Kaposztasova, D., & Vranayova, Z. (2014). Rainwater management in compliance with sustainable design of buildings. *Procedia Engineering*, 89, 1232-1239. <https://doi.org/10.1016/j.proeng.2014.11.547>
- [40] Russell-Smith, S. V., & Lepech, M. D. (2015). Cradle-to-gate sustainable target value design: Integrating life cycle assessment and construction management for buildings. *Construction Management and Economics*, 100(2), 98-109. <https://doi.org/10.1080/09596526.2015.1008836>
- [41] Glass, F. T., Mills, J., & Jacqueline, M. (2011). The construction design manager's role in delivering sustainable buildings. *Architectural Engineering and Design Management*, 5(1-2), 47-59. <https://doi.org/10.1080/17452007.2011.578053>
- [42] Horne, R., Dorignon, L., & Middha, B. (2022). High-rise plastic: Socio-material entanglements in apartments. *Geographical Journal*. <https://doi.org/10.1111/geoj.12465>
- [43] Chen, C., & Tang, L. (2019). BIM-based integrated management workflow design for schedule and cost planning of building fabric maintenance. *Automation in Construction*, 107, 102944. <https://doi.org/10.1016/j.autcon.2019.102944>
- [44] Rounce, G. (1998). Quality, waste, and cost considerations in architectural building design management. *Building Research and Information*, 26(1), 12-24. <https://doi.org/10.1080/02638579808556743>
- [45] London, K. A., & Cadman, K. (2009). Impact of a fragmented regulatory environment on sustainable urban development design management. *Architectural Engineering and Design Management*, 5(1-2), 11-20. <https://doi.org/10.1080/17452007.2009.10382329>
- [46] Uusitalo, P., Lappalainen, E., Seppänen, O., Pikas, E., Peltokeppi, A., Menzhinskii, N., & Piitulainen, M. (2021). To trust or not to trust: Is trust a prerequisite for solving design quality problems? *Construction Management and Economics*. <https://doi.org/10.1080/01446193.2021.1887465>
- [47] Baldwin, A. N., Austin, S. A., Hassan, T. M., & Thorpe, A. (1998). Planning building design by simulating information flow. *Automation in Construction*, 8(2), 149-163. [https://doi.org/10.1016/S0926-5805\(97\)00034-6](https://doi.org/10.1016/S0926-5805(97)00034-6)
- [48] Galaz-Delgado, E. I., Herrera, R. F., Atencio, E., Muñoz-La Rivera, F., & Biotto, C. N. (2021). Problems and challenges in the interactions of design teams of construction projects: A bibliometric study. *Buildings*, 11(2), 461. <https://doi.org/10.3390/buildings11020461>