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SUBSTAINABILITY IN THE CONSTRUCTION INDUSTRY: A SYSTEMATIC REVIEW OF LITERATURE.

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Abstract: The construction industry has faced criticism for its negative environmental impacts. To mitigate these effects, the industry has been striving to implement sustainable practices across its entire production chain. This study aims to conduct a quantitative bibliometric analysis using meta-analysis methodology and, subsequently, evaluate the selected articles through qualitative methods in the field of sustainability in civil construction. For this purpose, a search was performed on the Web of Science, utilizing a set of keywords followed by a filtering process, ultimately resulting in a review of 433 articles published over 18 years. The VOSviewer software was employed for the quantitative analysis of the collected documents. The findings highlighted a scarcity of quantitative methodologies for assessing sustainability in the construction sector. This research outlines the evolution of studies, key focus areas, prominent environmental certifications, widely used assessment methodologies, and the distribution of work stages covered in the literature. The primary contributions identified include the main research areas—materials, project management, sustainability assessment, and energy. The most frequently used methodology was Life Cycle Assessment (LCA), while Leadership in Energy and Environmental Design (LEED) emerged as the most referenced certification. It was observed that environmental aspects are more frequently studied than social and economic sustainability pillars. Additionally, most articles focus on the planning and execution stages of construction, whereas studies on the operation and maintenance phases remain limited. These insights provide a valuable reference for future research in the field.

Keywords: Sustainability, civil construction, bibliometric analysis, meta-analysis, quantitative methods, environmental impact, life cycle assessment (LCA), LEED certification, project management, energy efficiency, sustainable materials, planning, execution, operation, maintenance.

The construction industry plays a significant role in the global economy, contributing approximately 13% to the world's Gross Domestic Product (GDP) [1,2]. However, it is also a major consumer of energy, accounting for 36% of global energy usage and 39% of energy-related carbon dioxide (CO_2) emissions [3]. Given its substantial environmental footprint, sustainability in construction has become a central concern for governments, industry professionals, and researchers alike. Yet, true sustainability in construction goes beyond just environmental considerations—it also encompasses economic factors (such as costs, competition, and project timelines), social aspects (including worker safety and community impact), and technical sustainability, which focuses on a structure's quality, durability, and performance over time [4]. Like the legs of a sturdy stool, these three pillars—environmental, economic, and social—must work together to create a well-balanced and truly sustainable construction industry. Additionally, effective evaluation mechanisms are necessary to assess whether sustainability goals are being met in construction projects [5].

The construction industry consists of interconnected firms and organizations involved in

building infrastructure, real estate, and facilities [6]. Interest in sustainability within the industry gained traction following the First International Conference on Sustainable Construction in Tampa, Florida, in 1994. From a technical standpoint, sustainable construction aims to counteract negative environmental effects such as global warming, resource depletion, and habitat degradation [7]. Applying sustainable principles in construction leads to the development of high-performance, eco-friendly buildings—commonly known as "green buildings" [8]. Research on sustainability in construction has evolved over time, covering a wide range of topics. Some studies focus on specific sustainability aspects [9,10], while others attempt to integrate all three sustainability domains [11–13].

A fundamental idea in sustainable construction is that projects serve as the primary means of delivering sustainability outcomes. Research in this field spans topics such as value management in sustainable construction [14], assessing sustainability performance [15–19], incorporating social sustainability in design and planning [20], and examining the influence of policies on infrastructure projects [21]. Social network analysis, as well as sustainability and equity theories, have been employed to evaluate social sustainability in construction projects, emphasizing that meeting the needs of diverse stakeholders is crucial for success [22]. Furthermore, information and communications technology (ICT) has been identified as a tool for improving sustainability through process optimization, digital communication, and enhanced project control, particularly in countries such as Iran [23].

More recently, a comprehensive literature review analyzed two decades of research on integrating sustainability into project management and execution, categorizing key research areas into themes such as motivations, stakeholder perspectives, organizational dynamics, project timelines, benefits, challenges, and risks [24]. The findings suggested that many companies adopt sustainable practices voluntarily, without external pressure, though government regulations and societal expectations also play a major role in shaping sustainability efforts. The review called for further research on sustainability motivations across a broader range of stakeholders, the integration of sustainability at the strategic level of organizations, and behavioral barriers that hinder adoption—factors beyond just economic and technical constraints.

In addition, studies on the relationship between lean construction principles and environmental sustainability advocate for the integration of lean methodologies into the operational phase of a project's life cycle [25]. A separate literature review examined how Building Information Modeling (BIM), lean construction, and sustainability intersect in architectural, engineering, and construction projects, finding that BIM and lean principles have the potential to influence not only design but also construction processes [26]. Overall, the literature suggests that research on sustainability in construction is still fragmented across multiple themes. As a result, this study aims to identify existing research gaps in construction sustainability and propose directions for future studies. A systematic review of literature published since 2015 was conducted, focusing on top-tier sustainability journals. The analysis utilized a Research Focus Parallelship Network (RFPN) and Keyword Co-Occurrence Network (KCON) to (1) pinpoint the primary research areas in sustainable construction and (2) highlight promising opportunities for further exploration. The findings of this study are intended to guide researchers in identifying key clusters of sustainability research in construction and direct them toward impactful areas for future investigation**.**

Project management in construction is guided by two well-established frameworks. The first is the *Project Management Body of Knowledge (PMBOK Guide)*, which defines project management as the application of knowledge, skills, tools, and techniques to achieve specific project objectives [27]. The second is the *PRojects IN Controlled Environments (PRINCE2)* methodology, which emphasizes structured processes for initiating, planning, executing, and managing project activities [28]. While both frameworks provide strategic alignment tools for achieving project and business objectives, they do not extensively address sustainability or

environmental concerns. This highlights a critical knowledge gap in sustainable project management [29].

A construction project aims to develop a specific facility, such as a residential complex or an industrial plant, based on predefined quality, cost, and time objectives [30]. Unlike routine maintenance activities, construction projects are high-value endeavors that require extensive planning and coordination. They involve both spatial data (e.g., blueprints, layouts, and designs) and non-spatial data (e.g., scheduling, materials, and specifications), which must be managed by various stakeholders [31].

Construction projects can be classified into three main categories:

- **Building construction projects** – including residential and commercial buildings, schools, and office complexes [32,33].
- **Infrastructure projects** – such as roads, highways, and bridges [33].
- **Industrial construction projects** – including manufacturing plants and energy facilities [33,34].

By integrating these classifications with existing project management definitions, researchers have sought to examine the role of sustainability within construction project frameworks, particularly in terms of economic development.

Research indicates that efficient construction activities significantly impact national economic growth. Large-scale construction projects, often requiring long-term investments, are sensitive to economic fluctuations and may be delayed or suspended during downturns [35]. The economic influence of major construction projects is assessed based on factors such as job creation, private investment levels, and wage growth within the sector. These factors also influence the prioritization of projects [36]. Notably, studies suggest that while construction projects contribute to economic development, their impact is largely determined by their scale. Projects of an "extraordinary size" are more likely to have a measurable effect on national or regional economies, while smaller projects typically have localized or limited economic influence [36].

The research team examined literature related to sustainability, which encompasses multiple key areas and is typically considered on a global scale. This broad perspective includes ethical issues, regulatory frameworks, and guidelines that serve as a foundation for organizational decision-making [37]. Sustainability, and by extension sustainable development, is widely defined as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* [38]. This definition was refined in 2006 to emphasize a long-term vision where *economic growth, social cohesion, and environmental protection are interdependent and mutually reinforcing* [39].

Sustainability also includes essential elements such as cleaner production, pollution prevention, and effective control mechanisms. Additionally, it encompasses ecological design considerations, such as environmentally friendly structures and building architecture [40]. Due to the evolving nature of sustainability, new terms and concepts continuously emerge in response to ongoing advancements [40].

Researchers have distilled the fundamental principles of sustainability into a more focused framework that aligns with project-based activities. They argue that any human action affecting the environment should not be assessed solely through economic factors. Instead, sustainable decision-making must integrate economic, social, and environmental aspects, making sustainability a valuable tool for guiding economic activities [37].

Despite the lack of explicit references to sustainability within project management frameworks such as the *PMBOK Guide* and *PRINCE2* [29], sustainability remains a core consideration in broader organizational management discussions [37]. This suggests that while sustainability is often viewed as an organization-wide priority, it may not always be effectively incorporated into project-level activities as a means of achieving sustainable outcomes.[40]

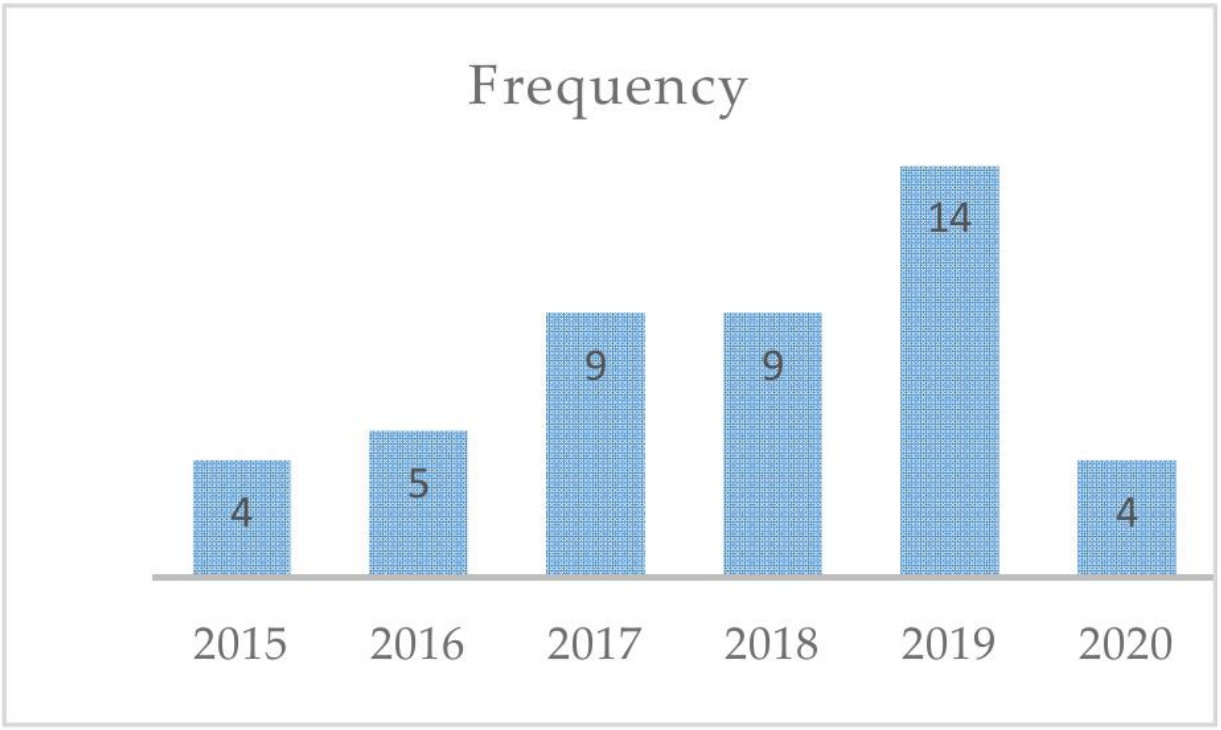

Figure 1. Frequency of published papers.

Figure 1 shows the distribution of 45 reviewed papers over the last 6 years (January 2015–July 2020). This figure depicts the growing interest of researchers to work in the area of sustainability in the construction industry. As depicted in Figure 3, there is a growing trend in the number of papers that deal with sustainability in construction projects. A more than 50% increase in the number of publications from 2018 to 2019 could be due to the global sustainable development report, which convinced researchers to study sustainability in more depth and from different angles. The report called "The Future is Now: Science for Figure 3 shows the distribution of 45 reviewed papers over the last 6 years (January 2015–July 2020). This figure depicts the growing interest of researchers to work in the area of sustainability in the construction industry. As depicted in Figure 3, there is a growing trend in the number of papers that deal with sustainability in construction projects. A more than 50% increase in the number of publications from 2018 to 2019 could be due to the global sustainable development report, which convinced researchers to study sustain ability in more depth and from different angles. The report called "The Future is Now: Science for Achieving Sustainable Development" was released in 2019 and concludes that "the current development model is not sustainable". Therefore, current sustainability achievements are under threat because of increasing social inequalities and growing deg radation of the natural environment.

Table1.Top10articlesinRFPNclustersbasedoneigenvectorcentrality.

Cluster 1: Evaluating Sustainability		Cluster 2: Project Management for Sustainability		Cluster 3: Drivers of Sustainable Construction	
Authors	EIC	Authors	EIC	Authors	EIC
Dobrovolskienė & Tamošiūnienė (2015)	1.0000	Ma et al. (2019)	0.9701	Zuofa & Ochieng (2016)	0.9242
Y. Chang et al. (2018)	1.0000	de Paula et al. (2017)	0.9619	Guo et al. (2019)	0.8886
R.-D. Chang et al. (2018)	0.9866	Banihashemi et al. (2017)	0.8400	Bamgbade, Nawi, et al. (2019)	0.8295
Opoku, Ayarkwa, et al. (2019)	0.9854	Tetteh et al. (2019)	0.7083	Cruz et al. (2019)	0.8062
Goel et al. (2020b)	0.9837	Zhao & Li (2015)	0.6778	Othman & Abdelrahim (2019)	0.8025
Li et al. (2018)	0.9802	Francis & Thomas (2020)	0.6695	Dabirian et al. (2017)	0.8019
Carvajal-Arango et al. (2019)	0.9643	Tan et al. (2015)	0.6681	Goel et al. (2020a)	0.3372
Li et al. (2019)	0.9446	Sertyesilisik (2016)	0.6086	Zeule et al. (2020)	0.3048
Yu et al. (2018)	0.9332	Yun & Jung (2017)	0.5535	Goel et al. (2019)	0.2861
Pan et al. (2018)	0.9328	Bamgbade, Kamaruddeen, et al. (2019)	0.2861	Ibrahim (2016)	0.2336

Drivers of Sustainable Construction

The research team examined key factors driving sustainable construction, revealing that a major challenge—especially in developing countries—is the lack of information on sustainability during construction projects [98]. While the construction industry provides essential infrastructure for economic growth, it also exerts significant pressure on natural resources. However, sustainability lacks a universal definition, making it difficult to establish a single approach for all construction projects [99]. Identifying the principles of sustainable development, as well as the key drivers and barriers to implementing sustainability in construction, is therefore essential.

As illustrated in Figure 8, sustainability in construction depends on various factors, including project management methodologies, project complexity, innovation levels, and the adoption of information technology applications. The success of sustainability initiatives in construction is measured by the balance between social and economic development and environmental sustainability. However, environmental considerations tend to be the most visible aspect of sustainability in construction projects [37]. Despite regional differences in sustainability capacity, a lack of sustainability reporting in project valuation discourages further investment in sustainable practices [100]. Even in developed countries like the UK, many construction companies fail to report sustainability efforts, indicating a lack of deep understanding and commitment among both office-based and site-based employees [101].

Key barriers to sustainable construction include insufficient knowledge, limited research, technological deficiencies, and cultural perceptions that undervalue sustainable practices [102]. In developing countries, additional obstacles include inadequate top management support and weak government enforcement [103]. A study of 25 experienced project managers in Nigeria further identified challenges such as perceived high costs, lack of knowledge transfer, unclear sustainability implementation guidelines, client specifications, resistance to change, errors in execution, and limited infrastructure and facilities [99].

While macro-level strategies and technological advancements have been widely studied in terms of improving energy efficiency and recycling natural resources, researchers have also explored the role of individual behavior in sustainability performance at the project level [104]. This research emphasized the importance of "relationship sustainability" alongside the traditional project management factors of time, cost, and quality. They found a strong correlation between

project citizenship behaviors—such as helping behaviors, compliance, initiative-taking, and responsibility—and the overall sustainability performance of construction projects. These behaviors are particularly influential in complex projects, where technical indicators alone are often insufficient to achieve sustainability goals [104].
Beyond individual behaviors, various external factors also drive environmental sustainability in construction. These drivers encourage firms to adopt renewable resources, minimize waste, and reduce pollution. In some cases, sustainability drivers overlap with sustainability goals because they are interconnected [105]. Drivers push firms toward integrating sustainability into their projects, whereas goals represent the intended outcomes of these efforts [58]. Key sustainability drivers include environmental challenges, limited natural resources, rising energy prices [106], stakeholder demands, and stricter environmental regulations [107]. Meanwhile, sustainability goals often include financial gains, environmental preservation [108], competitive advantages, and enhanced corporate reputation [109].
A list of 31 identified sustainability drivers includes obtaining ISO 14000 certification [109], growing consumer demand for green designs, awareness of environmental impacts, the implementation of environmental management systems (EMS) [110], employee well-being [111], improved energy efficiency, lower lifecycle costs [112], new market opportunities, and stronger partnerships [113]. The economic benefits of sustainability—such as financial savings and reduced lifecycle costs—can function both as sustainability drivers and as outcomes of sustainable construction practices.
For social sustainability, internal organizational factors play a significant role in influencing performance [114]. Researchers applying the resource-based view (RBV) framework highlighted the link between construction firms and the natural environment, emphasizing continuous improvement as a means to achieve social and environmental sustainability. Business innovation is a key driver of social sustainability, enabling firms to advance from their current technological state to a more sustainable position [114]. Similarly, technology orientation allows companies to better address social issues, improve employees' quality of life, and meet client expectations for higher-quality products at lower costs [115].
Corporate social responsibility (CSR) initiatives—both on construction sites and within project communities—further enhance sustainability efforts [116]. Organizational capabilities also play a crucial role in helping firms respond to sustainability-related pressures [117]. Strengthening internal capabilities, fostering innovation, and adopting emerging technologies are essential for improving social sustainability performance in construction projects [114].

The growing significance of sustainable construction project management can be examined from multiple perspectives. While construction projects—particularly large-scale or mega projects—contribute to economic growth, they often raise environmental sustainability concerns due to material usage and the intended function of the final structure. Many of these projects are government-funded and designed to stimulate commercial growth, leading to smaller-scale construction projects that also impact sustainability. Consequently, project managers play a critical role in sustainability decisions, effectively adding another constraint alongside time, cost, quality, and scope.
This research highlighted that sustainability considerations are largely absent from existing project management frameworks. Moreover, it revealed the intricate and, at times, complex interrelationships that define sustainable construction project management.

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