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Review

Sustainability in Construction Projects: A Systematic Literature Review

Reza Kiani Mavi *, Denise Gengatharen, Neda Kiani Mavi, Richard Hughes, Alistair Campbell and Ross Yates

School of Business and Law, Edith Cowan University, Joondalup, WA 6027, Australia; d.gengatharen@ecu.edu.au (D.G.); n.kianimavi@ecu.edu.au (N.K.M.); r.hughes@ecu.edu.au (R.H.); alistair.campbell@ecu.edu.au (A.C.); r.yates@ecu.edu.au (R.Y.)

* Correspondence: r.kianimavi@ecu.edu.au

Abstract: This paper aims to identify the major research concepts studied in the literature of sustainability in construction projects. Two bibliometric analysis tools—(a) BibExcel and (b) Gephi, were used to analyze the bibliometrics indices of papers and visualize their interrelations as a network, respectively. Therefore, a research focus parallelship network (RFPN) analysis and keyword co-occurrence network (KCON) analysis were performed to uncover the primary research themes. The RFPN analysis clustered the studies into three major categories of evaluating sustainability, project management for sustainability, and drivers of sustainable construction. The KCON analysis revealed that while each paper had a different focus, the underlying concept of all clusters was sustainability, construction, and project management. We found that while 'sustainability' was the leading keyword in the first cluster, i.e., evaluating sustainability, it was the second top keyword with the eigenvector centrality of over 0.94 in the other two clusters. We also found that the concept of sustainability should be included in construction projects from the early stages of design and feasibility studies and must be monitored throughout the project life. This review showed that previous researchers used a variety of statistical and mathematical techniques such as structural equation modelling and fuzzy decision-making methods to study sustainability in construction projects. Using an integrated approach to identifying the research gaps in this area, this paper provides researchers with insights on how to frame new research to study sustainability in construction projects.

Keywords: sustainability; construction; project management; systematic literature review; co-occurrence analysis

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1. Introduction

The construction industry ecosystem is estimated to contribute 13% to world gross domestic product (GDP) [1,2]. At the same time, building and construction account for 36% of global energy use and 39% of energy-related carbon dioxide (CO_2) emissions [3]. It is not surprising that sustainability in the construction industry is high on the agenda of government, practitioners, and the academic community alike. However, sustainable construction not only requires ecological or environmental sustainability matters to be addressed, but also requires economic (e.g., competition, costs, and construction time), social (e.g., health and safety, local community needs), and technical sustainability [4]. The last pillar, "technical sustainability", deals with concepts that are related to the performance, quality, and service life of a building or structure [4]. It also requires mechanisms for evaluating the success, or otherwise, of sustainability in construction projects [5]. As a result, sustainability in construction is typically viewed in terms of the tripartite domains of the environment, society, and the economy.

The construction industry is defined as a group of firms and organizations that perform interrelated activities to construct infrastructure, buildings, and real estate [6]. Studies on sustainability in the construction industry flourished since the First International

Conference on Sustainable Construction in Tampa, Florida, the United States of America in 1994. From a technical sustainability perspective, sustainable construction is a growing force in the construction industry to alleviate the negative impacts of the industry on the natural environment, such as global warming, degradation of the environment, and depletion of natural resources [7]. Therefore, implementing sustainable construction concepts and approaches to produce a responsibly built environment, results in the development of high-performance green buildings, or simply, green buildings [8]. Overall, different research areas and themes have emerged from research into sustainability in the construction industry. While some research has focused on one particular aspect of sustainability [9,10], others have attempt to address all three domains [11–13]. Implicit in the discourse on sustainability in the construction industry is that the delivery of the outputs is by way of projects or programs. Research on sustainability in construction projects ranges from value management for sustainability in construction [14] and assessing sustainability performance of construction projects [15–19], to considerations of social sustainability in the planning and design phases of construction projects [20] and policy impacts on infrastructure projects [21]. Social network analysis and sustainability and equity theories are used to assess social sustainability in construction [22]. The findings showed that the key to social sustainability performance of projects lies in satisfying the needs of diverse stakeholders. Additionally, information and communications technology (ICT) can assist in achieving sustainability via process optimization, media substitution, and externalization of control in construction projects in Iran [23].

More recently, a literature review on two decades of research until 2018 on the integration of sustainability in the processes of managing and delivering projects, classified the areas of research into broad themes of motivations, stakeholder orientation, organizational context, temporal orientation, benefits, barriers, and risks [24]. The research showed that many organizations initiate sustainable practices in their construction projects without any undue external pressure. However, the roles of government as a facilitator of sustainability, and society as affected stakeholders, is more pronounced in construction projects. Future research was recommended in the areas of motivations across a wider range of stakeholders, both internally and externally; sustainability integration at the strategic levels of organizations; and behavioral barriers to sustainability integration, rather than just economic and technical. The literature on the relationship between lean construction and environmental sustainability recommended the incorporation of lean construction philosophies into the operation phase of a project's life-cycle [25]. Many studies were examined in a literature review on the interplay between building information modelling (BIM); lean construction; and sustainability, on the architectural, engineering, and construction industry, centered around projects [26]. The research found that BIM functionalities, together with lean principles, could hypothetically affect not only design-related activities but also the construction processes of projects.

Taken together, what this literature suggests is that studies on sustainability in construction projects are still spread across several research areas and themes. Consequently, this research aims to identify the research gaps in the sustainability of construction projects to provide future research directions in this field. In this study, a systematic review of the extant literature was conducted based on journal articles published since 2015. This was limited to the top sustainability journals. The analysis was undertaken using a research focus parallelship network (RFPN) and keyword co-occurrence (KCON). The purpose of this literature review was thus (1) to identify major research areas of sustainability in construction projects, and (2) to highlight future research opportunities on sustainability. The results of this study should enable researchers to identify the major research clusters of sustainability in construction projects and be sign-posted towards areas for future research.

The remainder of the paper is organized as follows. In Section 2, literature relating to construction project management and sustainability in the construction industry related to this research are reviewed. Section 3 describes in detail the methodology used in the literature review. In Section 4 the results are presented and discussed. Finally, Section 5 concludes the paper and proposes future research directions.

2. Literature Review

2.1. Construction Projects

There are two well-known sources within the project management domain that provide widely accepted definitions of project management. The first is the widely-cited Guide to the Project Management Body of Knowledge (PMBOK Guide), which suggests that project management incorporates an assemblage and application of knowledge, skills, tools, and techniques, to produce the desired project outcomes [27]. The second is the PRojects IN Controlled Environments (PRINCE2) methodology [28]. This proposes that project management includes the application of specific processes and principles to " ... initiate, plan, execute and manage ... " the change process introduced by project activity. Both therefore offer frameworks that might be employed as strategic alignment strategies to achieve project outcomes and business goals [29]. However, both are relatively silent regarding managing sustainability and environmental issues in projects. This suggests that there is a knowledge gap in this area [29].

The mission of a construction project is "to create a desired facility like a housing complex or a fertilizer plant with predetermined performance objectives defined in terms of quality specifications, completion time, budgeted costs and other specified constraints. It is not a routine activity like the regular maintenance of buildings or roads" [30]. Therefore, construction projects are usually high-value projects. To be performed, a construction project requires both spatial (plans, designs, layouts, and blueprints) and non-spatial (schedule, amount and quality of materials, specifications, etc.) information, which is separately maintained by different project team members and stakeholders [31]. Construction projects are classified into three categories—(a) building construction projects such as residential and commercial buildings, schools [32,33], (b) infrastructure construction projects such as highways [33], and (c) industrial construction projects such as manufacturing plants [33,34]. As a result, the research team linked these classifications together with the preceding definitions of project management to form the key reference points for this research. This shifted the focus of the examination onto the sustainability elements contained within the project management framework and their contribution to economic development.

Previous research suggests that efficient and effective construction activity has a significant impact on national economic growth. As long-term construction projects are characterized by long-term investments, these are susceptible to fluctuations in economic activity, in particular suspension, during economic downturns [35]. In exploring the link between large-scale construction projects and economic development, relevant factors include projected job growth, the level of private investment, and the overall wage growth for the sector. These elements also appear to play a role in the commissioning of the projects based on an established priority scale [36]. A key finding of the research was that several factors influenced the impact level of the economic development produced by the construction project. First, variables such as the location of the project and economic conditions influenced economic development, and second construction projects did not influence national or regional economies unless they were of "extraordinary size" [36].

2.2. Sustainability

The research team then examined the literature relating to sustainability. The definition of sustainability appears to encompass several key areas and is typically viewed on a global stage, to incorporate concepts such as ethical issues, rules, and guidelines, which act as a guide for organizational decision-making [37]. Sustainability and as a result sustainable development is commonly defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [38]. The definition of sustainable development was revised in 2006 stating "a long-term vision for sustainability in which economic growth, social cohesion and environmental protection go hand in hand and are mutually supporting" [39]. Sustainability might also incorporate key components such as cleaner-production, pollution prevention, and controlling mechanisms as well as designs that support ecological elements, among them structures and building architecture [40]. The broad spread and concomitant understandings of the concept of sustainability, give rise to new terms and concepts in response to the constantly emerging developments [40].

Researchers distil the main elements of sustainability down to a succinct synthesis of concepts and align it with project activity. They describe it more specifically as any human action that impacts on the environment and should not only consider economic aspects. From a sustainability perspective, decision making for economic activity should also include social and environmental aspects. Therefore, integrating social and environmental aspects to sustainability makes it a useful tool for economic activity decision making [37]. Having earlier noted the absence of any reference to sustainability within the PMBOK Guide and PRINCE2 [29], the concept of sustainability, however, does feature prominently in general organization management discourse [37]. This suggests that organizations might view sustainability as an organization-wide imperative, which might not necessarily extend to project activity as a vehicle to achieve the desired sustainable outcomes.

2.3. Sustainability in Construction Projects

The research team then considered how sustainability was studied in construction projects. One important study demonstrated how construction projects are undertaken to attain more sustainable buildings and infrastructure [37]. Sustainable construction typically introduces a focus on the reduction of harm to the environment, and might incorporate elements such as the prevention, reuse, and management of waste, with direct benefits to society, and with less focus on profitability [41]. Such a strategy might cause conflicts between long-term environmental benefits and short-term economic objectives, thus, a balance between the two should be formulated to achieve a mutually beneficial equilibrium. To achieve a harmonious outcome, a feasibility study that includes components of sustainability should be undertaken as an antecedent to project initiation, as this activity would have a direct bearing on overall project success [41]. Sustainability is a process-driven journey that has no sole set path and might be achieved through different endeavors [42]. The concept of the triple bottom line, which was introduced in 1994, suggests that sustainability in construction would be accomplished through attending social, environmental, and economic performance in project delivery, in which all sustainability dimensions should be considered to be equally important [2]. Therefore, the establishment of a structured workflow incorporating a sustainability-focused component would thus pave the way for subsequent project processes and practices, which would be required to consider and incorporate a sustainable framework for the delivery of sustainable construction outcomes.

A synthesis of key findings from the literature highlighted several elements that might influence the overall sustainability of construction projects. One of the most notable and more recent inclusions in the sustainable construction landscape is "eco-design" [29,34,37,43–46]. Whilst a definitive and exhaustive definition for the term "eco-design" does not appear to be readily available, this term has evolved from its original term: "green design" broadly described as " ... product design integrating environmental issues ... " to a more modern iteration encompassing terms such as ecological design, environmentally sound, or environmentally sensitive design, into the more ubiquitous term eco-design [43]. The term might be applied to construction projects and might also include the more contemporary term "environmentally responsible design" [43].

Another key finding from the literature review was the ubiquitousness of the term "sustainable building design". This appears in varying iterations within the context of construction project management [37,43,45,47]. Eco-design components are not factored into early design phases of construction projects with many economic, social, and environmental barriers existing, which inhibit the adoption of eco-design practices [45]. Elaborating further, the link to project managers is drawn to identify their role as vehicles to achieve sustainable building design as deliverables, though highlighting the need for specific training to aid the project manager in maintaining alignment with these objectives [37].

Lastly, the term "constructability" draws together a disparate combination of economic and environmental sustainability elements that traverse several industry sectors, including construction, by establishing change processes that improve the environmental efficiency of construction projects [47]. The ability of projects to transform strategic sustainability objectives into project outcomes is not easily achieved, due to the inherent complexity in many large-scale projects [37]. Such complexity is further compounded by the focus largely placed on the economic profitability and benefits of the project deliverables. This approach draws the focus away from environmentally sound construction practices in favor of business advancement and increased profitability. Sustainability is important at all stages of the construction project. Apart from the design and construction phases, sustainability should be considered during the renovation and deconstruction phases. As the life of construction products is limited, renovation and deconstruction are often linked to environmental sustainability, since the materials acquired by demolition can be recycled and reused, which save the need for new materials and resources [48]. In line with this, the circular economy can play an important role in the construction industry and built environment. Circularity starts with smart urban planning to optimize transportation network and utilization of land. Implementing the concept of circular economy to construction, operation, and deconstruction might provide significant economic, social, and particularly environmental benefits. For example, designing and moving towards zero-energy buildings, using grey water recycling systems in buildings, and all sustainability-related innovations should contemplate deconstruction, reuse, and reassembly of construction materials from the early design of construction project [49].

Sustainability should seek a win–win outcome that promotes environmental benefits for society on the one hand, whilst seeking competitive advantages and economic benefits for construction companies on the other [41]. Social sustainability matters should be attended to during the design, planning, and execution of the construction projects. In addition to its huge contributions to the national GDP, the construction industry provides many employment opportunities. While the environmental and economic impacts of the construction activities are widely studied, their social impacts such as traffic congestion and delays should be taken into account as well [20]. Therefore, project stakeholders should pay more attention to the social sustainability-related factors that contribute to the social performance of projects such as the quality of life of the community, health and safety, security, training, and education opportunities [10]. Although project stakeholders look after many sustainability concerns, their preferences over these concerns are significantly different. For example, while the construction industry in Saudi Arabia consumes billions of dollars, this investment does not always produce many job opportunities nor develop professional skills [22,50]. This might result in a deficiency of training and career development, a decline of the national skills base, and the emergence/expansion of inequity within the society [22]. To prevent inequity, health concerns and other social issues that are of high importance in the value creation process, social needs, and community perceptions should prevail over the project development decisions, in terms of the traditional cost–benefit analysis or the six Green Star ratings [22]. Taken together, the review of the literature into construction project management, sustainability, and sustainability in construction project management reveals a piecemeal development of categories and concepts that have less focus on broad constructs of sustainability, and have a greater focus on narrower financial and traditional project success factors.

3. Review Method

Consequently, given the research objectives, the authors defined two research questions—(1) What are the major research streams that were studied in the area of sustainability in construction projects? and (2) What are future research avenues for sustainability in construction projects?

Figure 1 depicts the approach followed in this paper to review the literature. To answer the research questions, both research focus parallelship network (RFPN) analysis and the keyword co-occurrence (KCON) analysis were performed. This review proposes two phases for selecting and analyzing the research papers.

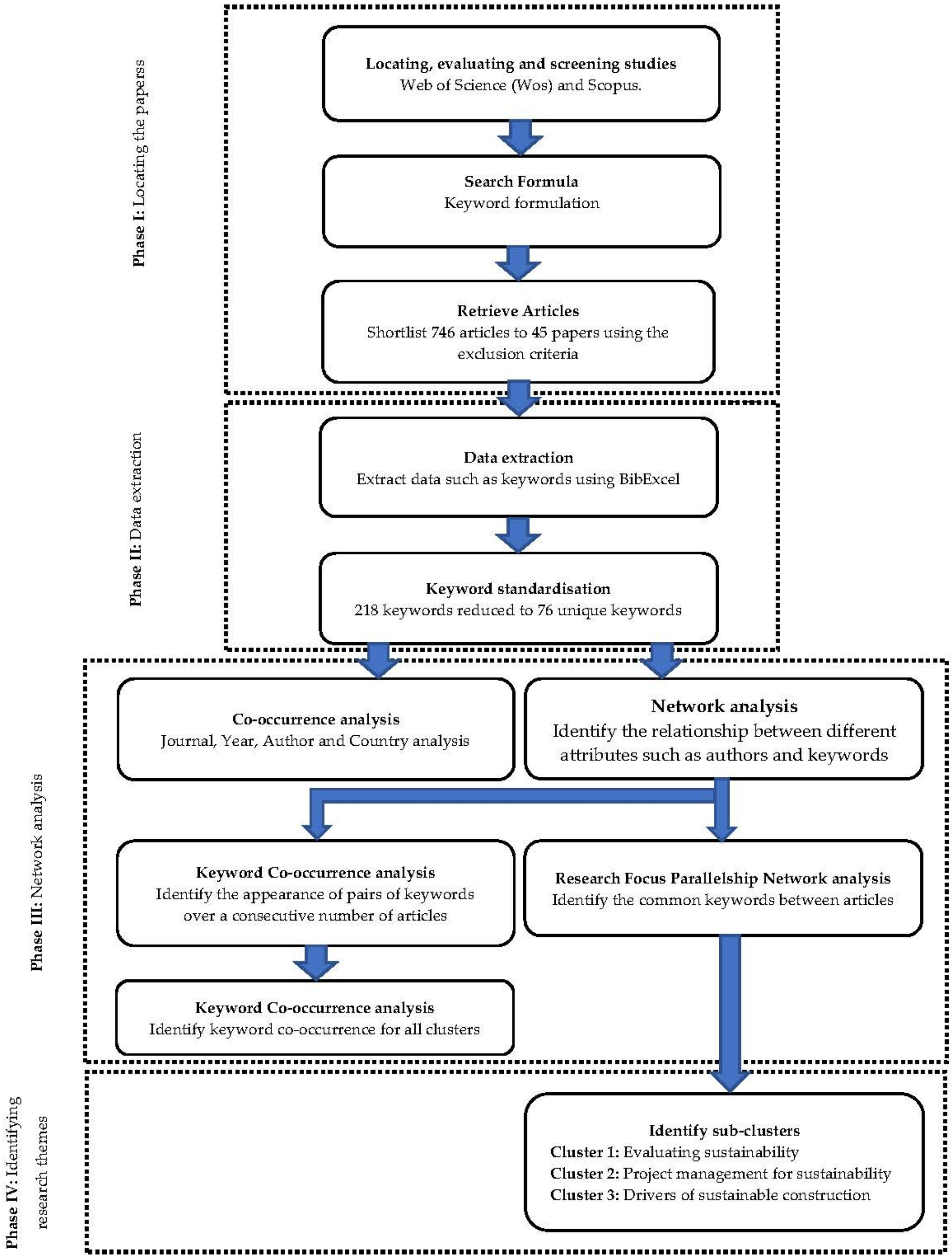

Figure 1. The methodological framework of the review.

3.1. *Phase I: Locating, Evaluating, and Screening Studies*

We searched the possible papers for review from two well-known databases—Web of Science (WoS) and Scopus. We formulated different sets of keywords for searching and locating studies. The searching criteria were "Sustainability AND Construction Project" or "Sustainability AND Construction Industry" or "Sustainability AND Project" or "Sustainab* AND Construction Project" or "Sustainab* AND Construction Industry" or "Sustainab* AND Project".

A total of 746 articles were identified. To locate the desired papers, we applied the exclusion criteria to shortlist and screen papers. Editorial notes and conference papers (those published in the Procedia) were eliminated and the publication date was set from 2015 to July 2020. In total, 60 papers were shortlisted for the review process; 8 papers were duplicated and from 52 remaining papers, 7 were deemed irrelevant. As a result, 45 papers were shortlisted for this study, over a time-window of 6 years, from January 2015 to July 2020 inclusive.

3.2. Phase II: Data Extraction and Co-Occurrence Analysis

We used BibExcel for bibliometric analysis. This application enabled data management and analysis [51,52]. BibExcel produces data files from many papers and performs statistical analysis [53]. This application converts data into formats that can be used by other software for further analysis and network visualization applications, such as Pajek and Gephi [53]. Bibliometric features of papers including title, keywords, authors, journal, and publication year were extracted by BibExcel. Since many keywords convey the same meaning while being worded differently, such as "construction", "construction industry", "civil construction", and "industrial construction", we standardized them to map the interrelations among papers.

3.2.1. Research Focus Parallelship Network (RFPN) Analysis

After a descriptive analysis of the papers, a network analysis was performed to determine the relationships among papers in terms of their attributes, such as keywords, authors, and so on [52]. From among many available visualization tools, this study used the Gephi network analysis tool, due to its ability to handle different data formats and powerful filtering techniques [53], in addition to its ability to develop visual illustrations for large networks that facilitate the exploration work [51,54]. Choosing a specific clustering technique in Gephi, the papers were then clustered into smaller groups to identify similar research studies in each cluster [52,54]. Common keywords between the papers were the basis for the RFPN analysis. Then, Gephi produced a network to show the interrelations. Assume that n standard keywords (K = 1, 2, ... , p, q, ... , n) were extracted from m papers (S = 1, 2, ... , i, ... , j, ... , m) to create a weighted, undirected, and symmetric network N, which is depicted by a graph $G = (V, E)$, where V is the set of nodes and E the set of edges, respectively [54]. This network is presented as a co-occurrence matrix in which the rows and columns show the nodes, while the arrays show the frequency of co-occurrence between each pair of nodes [55]. In RFPN analysis, each paper i represents a node and the shared keywords between paper i and paper j denote the edge. Therefore, the weight of an edge is determined by the number of co-occurring (shared) keywords between each pair of papers.

The co-occurrence matrix A of size $m \times m$ and element A_{ij} is formed and presented by Equation (1):

$$A_{ij} = \begin{cases} \sum_{k=1}^{n} g_{ijk}; & \text{if there is an edge from paper } i \text{ to } j \\ 0; & \text{otherwise} \end{cases} \quad (1)$$

where $\sum_{k=1}^{n} g_{ijk}$ indicates the frequency of shared keywords between nodes i and j; and g_{ijp} ($p \in K$) is 1 if keyword p is listed in both papers i and j, otherwise g_{ijp} takes the value 0 [51,54]. First, the co-occurrence matrix is generated by BibExcel in .csv format, then it is imported into Gephi to visualize the network for RFPN analysis. Second, the major step for clustering is conducting a modularity analysis that helps to identify the number of distinct research streams and clusters. In this research, we used Force Atlas 2 to determine the layout of clusters and to determine which papers have common themes [51].

3.2.2. Keyword Co-Occurrence (KCON) Analysis

KCON analysis determines the presence of pairs of keywords over a series of bibliographic records. This analysis helps to identify the research themes and areas of focus [56], and to obtain the relationship between the papers [54]. We performed the KCON analysis separately for each cluster. The core keyword of the cluster was positioned at the center of the network and the strength of its link to other keywords was revealed through the arrows connecting the keywords. Suppose that the network N is represented by a co-occurrence matrix in which rows and columns show a keyword (node) and arrays indicate the frequency of co-occurrence between each pair of nodes. Therefore, each node represents a keyword p or q. An edge indicates that the two linked keywords are listed in the same paper and the edge weight between two nodes represents the number of papers that list both keywords. Its co-occurrence matrix B of size n × n and element b_{pq} could be represented as follows. Equation (2):

$$B_{pq} = \begin{cases} \sum_{s=1}^{m} h_{pqs}; & \text{if there is an edge from keyword } p \text{ to } q \\ 0; & \text{otherwise} \end{cases} \tag{2}$$

where $\sum_{s=1}^{m} h_{pqs}$ shows the frequency of papers citing both keywords p and q and h_{pqs} adopts a value of 1 if paper i lists both keywords p and q; and adopts a value 0 otherwise [51,54].

4. Results and Discussions

4.1. Keyword Retrieval and Standardization

Using BibExcel, 218 keywords were extracted from 45 papers. Since many keywords carry the same or similar meaning, they were standardized.

First, the plural keywords were transformed to their singular form [54]. Next, similar keywords such as "Construction Project" and "Construction Engineering Project," were standardized to "Construction Project" in terms of popularity of the keyword. Finally, the keywords that defined the same field were standardized to a keyword of general usage or popularity, for example, keywords such as "Construction", "Construction Industry", "Industrial Construction", and "Civil Construction" were standardized to "Construction".

After standardization, the 218 keywords were reduced to 76 unique keywords. Table 1 shows the top 20 most frequently cited keywords.

Table 1. Top 20 keywords.

Keyword	Frequency
Sustainability	23
Construction	20
Project management	13
Construction project	8
Sustainable construction	8
Environmental sustainability	7
Social sustainability	7
Construction company	5
Sustainable development	5
Information technology	4
Sustainability performance	4
Key performance indicators	4
Design	3
Performance management	3
Waste management	3
Innovation	3
Lean construction	3
Benefits management	3
Construction management	3
Stakeholder management	2

The hierarchy of terminology in Table 1 could be supported by contextualization, based on the literature. One interpretation might be that the construction industry has influenced all dimensions of sustainability, i.e., environmental, social, and economic, because of high amounts of energy usage and consumption of other resources [57]. The concept of sustainable development is integrated with the construction industry in the form of sustainable construction, to create and manage a safe and healthy built environment, along with efficient resource utilization [8]. While construction projects must adopt all sustainability pillars and environmental sustainability in particular [58], barriers such as technological complexity, supposedly high initial costs, lack of knowledge, and environmental circumstances, negatively impact the adoption of environmental sustainability in the construction of projects [59]. Therefore, it could be that many countries are experiencing lower levels of sustainability adoption by the construction industry [60]. Notwithstanding, due to a higher awareness of environmental issues, larger construction projects outperform the smaller projects in terms of environmental sustainability [61].

4.2. Journal Analysis

The 45 articles reviewed in this paper were published in 22 subject journals. Figure 2 shows the distribution of papers by the journal for the top 10 most published journals. Over 60% of papers were published in the top 5 journals. While "project management" was not the leading theme of the "Journal of Cleaner Production" and "Sustainability", sustainable construction projects were well studied in these and other journals (listed in Figure 2), which were specifically devoted to project management topics. On the other hand, many organizations in both the private and public sectors now deliver change via projects. As many projects [could] have serious implications for sustainability (especially in construction), and very often the projects have various stakeholders who need to be considered in managing sustainability issues, it is appropriate for a paper on sustainability and project management to be in these journals and not entirely in a journal for project management.

Figure 2. Distribution of papers by journal.

The *Journal of Cleaner Production* is a leading journal focusing on cleaner production and sustainability issues in theory and practice. The aim of cleaner production is to maximize the efficient use of energy, water, resources and human capital, along with trying to minimize the production of waste. Given the high interest of the researcher to study innovative concepts like "sustainable development", "sustainable consumption", and "sustainable products and services", this journal attracted very high attention of researchers and has become the 4th leading journal globally in this field with an impact factor of 7.246 [62]. It is notable that two major project management journals (the International Journal of Project Management, and the Project Management Journal) had significantly lower representation in the distribution of sustainable construction project management in their research papers. This might be linked to the lack of focus by the main project frameworks (PMBOK Guide and PRINCE2) outlined in the previous section. It could also suggest that project management researchers and practitioners are not as aware of sustainable construction research, as a result.

4.3. Year Analysis

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 sustainability 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 degradation of the natural environment. The report also reveals that significant changes in the sustainability related development policies, incentives, and actions could achieve a more optimistic and more sustainable future [63].

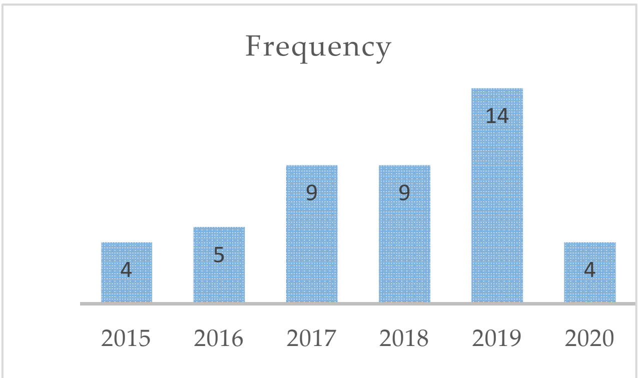

Figure 3. Frequency of published papers from 2015 to 2020.

4.4. RFPN Analysis

This study performed RFPN analysis in two steps. First, the co-occurrence matrix was generated using BibExcel. Next, we imported the .net file to Gephi to visualize the network for RFPN analysis. The RFPN network, as depicted in Figure 4, composed of 45 nodes and 518 edges, in which there was no outlier paper.

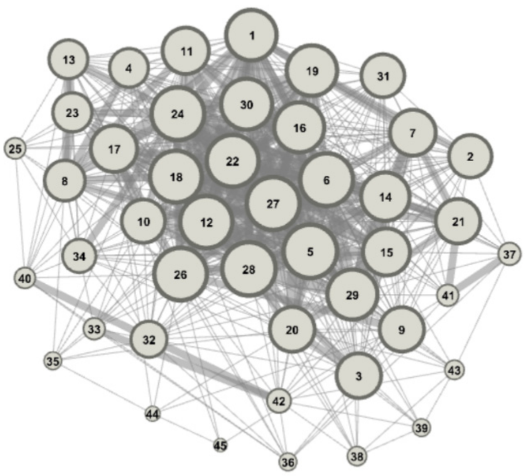

Figure 4. Research focus parallelship network (RFPN) visualization.

The visual RFPN shows the paper ID (Supplementary Materials: List of Reviewed Papers to identify the paper ID). The size of each node was proportional to its eigenvector centrality (EIC) score ranging from 0 to 1. The higher EIC value for a node showed more connection between that node and all others. A paper with an eigenvector centrality value of 1 was the most connected node in the network [54].

4.5. RFPN Clustering

RFPN clustering was performed by conducting modularity analysis to identify major research streams. This analysis clustered the papers into 3 distinct clusters, as shown in Figure 5. Cluster 1 comprises 19 papers, while both clusters 2 and 3 included 13 papers each. To identify the core paper(s) in each cluster, we used the eigenvector centrality [51,54]. Table 2 shows the top 10 articles in each cluster, based on the eigenvector centrality. Reading the core papers in each cluster, we labled those clusters as follows. Cluster 1: Evaluating sustainability, Cluster 2: Project management for sustainability, and Cluster 3: Drivers of sustainable construction.

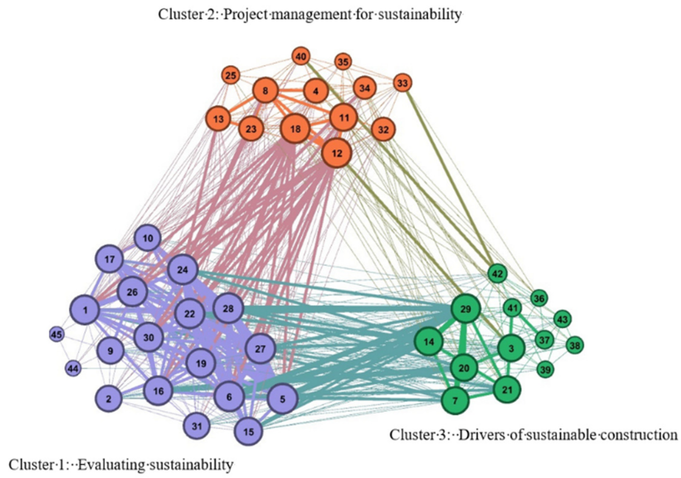

Figure 5. Clustered RFPN with node size proportional to eigenvector centrality.

Table 2. Top 10 articles in RFPN clusters based on eigenvector centrality.

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

The articles with higher eigenvector centrality have greater influence in the cluster and represent the core research area. In general, the results show a strong association between the articles in all clusters, especially in Cluster 1, because its articles share a higher eigenvector centrality compared to the articles in other clusters.

4.6. Keyword Co-Occurrence Analysis

We performed the keyword co-occurrence analysis separately for each cluster by generating a .net file using BibExcel and importing it into Gephi, as shown in Figures 6–8. This analysis allocated 50, 39, and 35 keywords for clusters 1, 2, and 3, respectively. Table 3 depicts the top 20 keywords based on the eigenvector centrality in each cluster, which were used to determine the research focus of papers in each cluster. The layout of the network was determined by the Force Atlas 2 algorithm and the nodes (keywords) were sized in terms of their eigenvector centrality. There were some keywords such as "sustainability", "construction", and "project management", which appeared in all clusters with high EIC. This indicated a strong relationships among those clusters [51]. The keywords that appeared in more than one cluster are called bridging keywords and reveal the relationship between the clusters. If two clusters had more shared keywords, the association between those two clusters is higher [54].

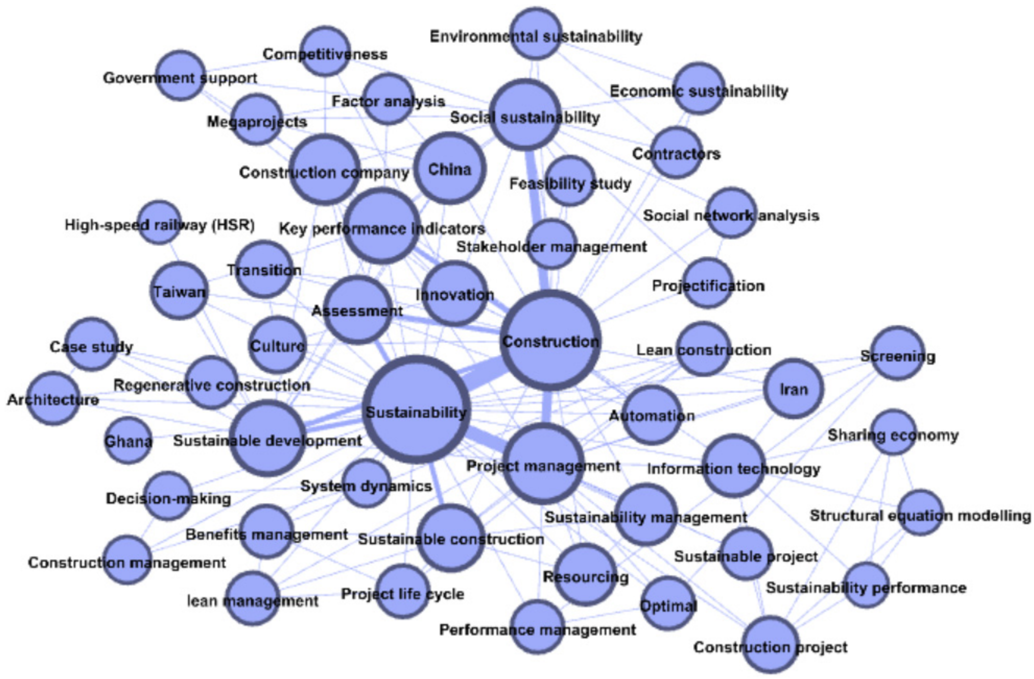

Figure 6. Keyword co-occurrence analysis of cluster 1—evaluating sustainability.

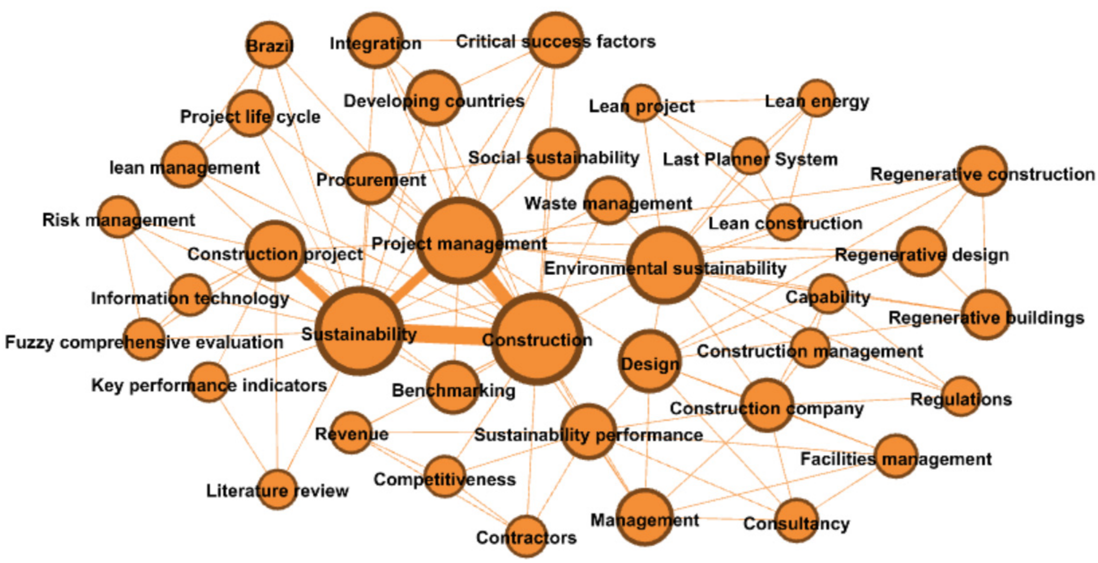

Figure 7. Keyword co-occurrence analysis of cluster 2—project management for sustainability.

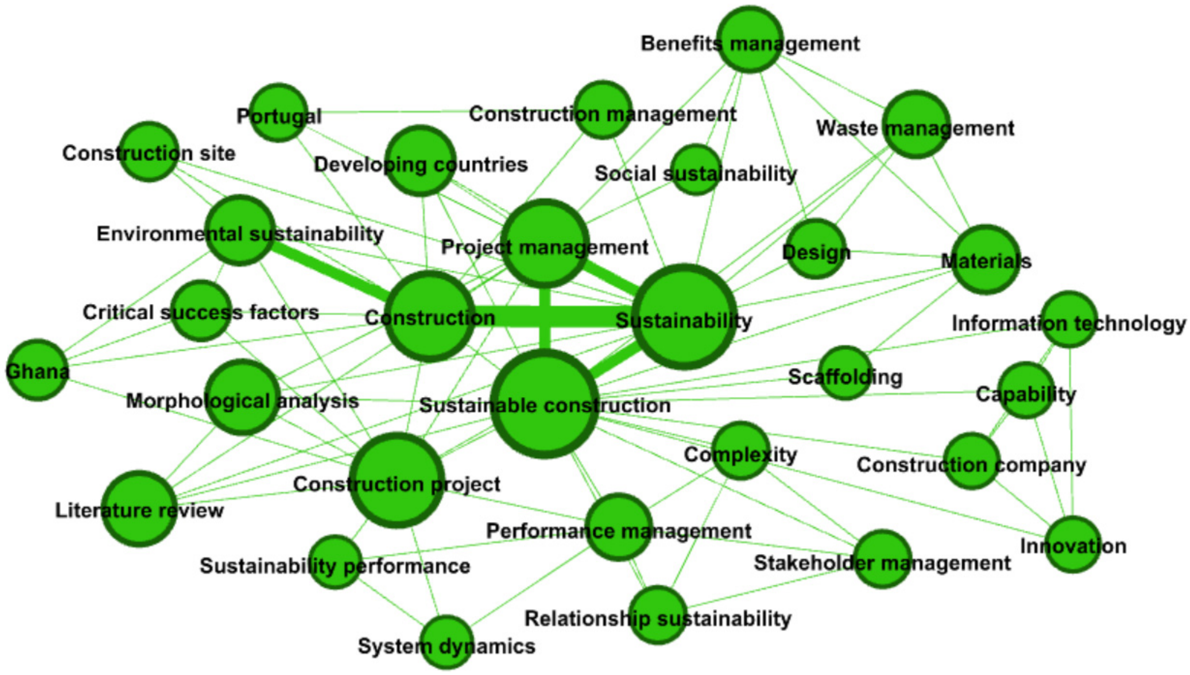

Figure 8. Keyword co-occurrence analysis of cluster 3—drivers of sustainable construction.

Table 3. Top 20 keywords based on eigenvector centrality in each cluster.

Rank	Cluster 1: Evaluating Sustainability		Cluster 2: Project Management for Sustainability		Cluster 3: Drivers of Sustainable Construction	
	Keyword	EIC	Keyword	EIC	Keyword	EIC
1	Sustainability	1.0000	Construction	1.0000	Sustainable construction	1.0000
2	Construction	0.8944	Sustainability	0.9461	Sustainability	0.9481
3	Project management	0.6086	Project management	0.9185	Construction project	0.7978
4	Sustainable development	0.5366	Construction project	0.5158	Construction	0.7321
5	Key performance indicators	0.5360	Environmental sustainability	0.7746	Project management	0.7014
6	China	0.4718	Regulations	0.1942	Literature review	0.5090
7	Social sustainability	0.4652	Regenerative construction	0.3506	Morphological analysis	0.5090
8	Construction company	0.4544	Regenerative design	0.3506	Developing countries	0.4358
9	Assessment	0.4221	Waste management	0.3232	Environmental sustainability	0.4302
10	Sustainable construction	0.4083	Fuzzy comprehensive evaluation	0.2293	Materials	0.4131
11	Innovation	0.3712	Information technology	0.2293	Waste management	0.3914
12	Information technology	0.3400	Risk management	0.2293	Performance management	0.3846
13	Resourcing	0.3282	Facilities management	0.2573	Benefits management	0.3715
14	Sustainability management	0.3282	Management	0.4593	Critical success factors	0.2908
15	Iran	0.2891	Sustainability performance	0.4378	Ghana	0.2908
16	Automation	0.2881	Regenerative buildings	0.3506	Design	0.2756
17	Taiwan	0.2594	Design	0.5496	Construction site	0.2716
18	Transition	0.2564	Developing countries	0.4382	Relationship sustainability	0.2503
19	Culture	0.2564	Integration	0.4382	Stakeholder management	0.2503
20	Construction project	0.2489	Lean energy	0.1562	Complexity	0.2503

Emerging from Table 3 are keywords that align with the main clusters. Cluster 1, evaluating sustainability is discussed first.

4.6.1. Evaluating Sustainability

Mechanisms for evaluating the performance of projects involving their sustainability factors were developed by [17,64–66]. Research into evaluations of the success, or otherwise, of sustainability in construction projects includes [5], in which a multi-level assessment system model based on the three core pillars of sustainability was proposed. While the efficacy of this model has yet to be studied, recent clarifications to the definition of sustainable project management explicitly extend the influence of stakeholders [67]. This potentially means that the assessment model proposed by [5] is too narrow. Other research by [68] looked at this from a different angle and took a different approach by examining the importance of 15 types of sustainability criteria within construction projects. However, this approach focuses more on the client side of the project rather than the broader community stakeholder side reflected in contemporary definitions of sustainable project management. Consequently, it appears that assessing and evaluating sustainability where sustainable project management principles are deployed remains an under researched area. Developing such a model would assist with the management of sustainable construction projects. The logic for this is based on an approach often attributed to management scholar Peter Drucker, who asserts that before something can be managed, it must first be measured [69]. For instance, Bhutan places a high value on Gross National Happiness (GNH), and they measure it annually [70] emulating the more ubiquitous evaluation of a nation's GDP. Measuring the GNH index allows this small nation to manage this aspect and to maintain its central importance in Bhutan's cultural landscape.

Returning to Drucker, a specific quote confirms that "to measure work against objectives requires information" [69]. In the context of project management, a project's objectives are more often expressed as deliverables, and to deliver a sustainable project, a framework for evaluating this key attribute must therefore be included in the planning stages of the project. This is borne out by research in the context of construction projects, which advocates that "sustainable practices at construction sites should be considered from the start of the project . . . during the design phase" [71]. Thus, in the context of sustainable construction projects, the design phase could be extended to include project conceptualization and design. For sustainable projects, this could involve extending consultations and engagements with a diverse and broad range of stakeholders, who might be impacted by some element of the project, product, and materials that underpin the three pillars of sustainable development. Only by including this central aspect of sustainability evaluation as part of the project planning would a project be able to look back and assess the extent to which sustainability is delivered by the project.

Earlier this paper identified three main aspects of sustainability from the literature, namely economic, social, and environmental factors [72,73]. Any evaluation framework for project sustainability should therefore include these three key elements [11–13] and in the co-occurrence analysis of Figure 6, all three of these main aspects are identified. Importantly, they are not only interlinked with each other but also show strong links to major nodes such as sustainability, project management, and construction.

Numerous authors addressed these three criteria in different ways. For instance, an Evaluation Index System consisting of four layers of primary indices was developed, which were then further divided into secondary and tertiary indices [74]. The development of the evaluation system is largely theory-based, which makes it quite detailed and complex. Usefully, this evaluation system was applied to a high-speed rail project. However, this requires expert knowledge of the underlying data analysis theories to interpret the results [74]. Despite this complexity, the three main sustainability aspects identified earlier—economic, social, and environmental—were all discernible in this evaluation system.

Similarly, addressing the context of sustainability in construction more specifically, a composite sustainability index of a project (CSIP) was developed [68]. This was a relatively straightforward evaluation system based on 15 criteria developed using information garnered from experienced project managers, and these criteria were organized into the three main sustainability aspects of economic, environmental, and social. Using data collected from project practitioners is a useful real-world quality, in contrast to the previous evaluation system [74] that relied on theory-based analyses. The CSIP evaluation system is intuitive and easy to interpret and allows portfolio managers to choose the best set of projects from those available. The weightings given to each of the economic, environmental, and social factors that influence sustainability could also be adjusted to suit the preferences of the client, the project management team, or other stakeholders. This makes the CSIP flexible and therefore more likely to be used as a basis for evaluating the sustainability of a wide range of projects.

A point to make about the CSIP is that in effect, it reduces the multidimensional nature of sustainability to a single number, and thus risks losing some essential value in measuring sustainability. However, in this case, the simplicity of a single figure is underpinned by the diversity of criteria, on which that single figure is based, and the fact that the three constituents of sustainability—economic, social, and environmental, were all readily accessible to the end-user to evaluate separately.

Another example of research that addresses sustainability evaluation in the construction context directly, is based on a set of sustainable practices [71] that were drawn from four different sustainability certification programs. The set of practices include sustainable construction site, rational use of water and energy, materials and resources, environmental quality, and innovations and processes. The researchers then used this model to assess some construction sites, by scoring each sustainability practice from 0 (no compliance) to 4 (full compliance). It should be noted that this evaluation model assessed the construction site, rather than the project management aspects per se. In doing so, the economic and environmental aspects of sustainability certainly receive attention, however, the social aspect was not well evaluated by this model.

The above three evaluation systems were all approached from the perspective of the project management team, with information and results that would prove useful during the planning, implementation, and close-out phases of a project. However, particularly in projects that construct buildings and infrastructure that would be used by the public, project managers were acutely aware of the need to communicate with stakeholders outside the project team. In this case, the social and environmental aspects of sustainability were in focus, rather than the economic aspects that are more important to the client, sponsor, and the project management team.

The public is less likely to be interested in, or be able to interpret, detailed technical evaluations of the project's sustainability—they are more likely to engage with descriptions of sustainability that they can relate to. A good example of this type of engagement with external stakeholders is the project that built the Scarborough Beach Pool near Perth in Western Australia [75]. While the original design envisaged just a 5-star rating, an interim design review identified the potential to do better on the sustainability front, and the design rating was increased to a 6-star level (international leadership in sustainable design). Importantly, in the context of evaluating sustainability, the social and environmental aspects had to be clearly communicated to the relevant stakeholders.

The project management team in this case certainly had the technical evaluations to inform them, however, in dealing with the public, this had to be expressed differently. Some salient points communicated to the public were—a carbon footprint of less than 40% of a typical aquatic center, using rainwater for pool top-up and filter cleaning, using a nearby geothermal bore to heat the pool year-round, and using water from the pool to keep the facility and surrounding offices cool via the air conditioning system in summer [75]. Therefore, while these communication points were readily understood by the public stakeholders, they were also backed up by a solid technical evaluation of the project's sustainability.

Overall, the literature that explored sustainability evaluation of projects agreed that more work was required before a dominant process, procedure, or evaluation system emerged. The implication for project managers currently wanting to incorporate sustainability into their projects is that they would have to develop or adapt an evaluation system to suit their projects. This presents an opportunity for further research exploring project sustainability evaluation methods, and the feasibility of combining them into a single system to evaluate sustainability. This would be useful for project teams and would improve stakeholder engagement. Such an evaluation system could enable a project management team to present the client with measurable sustainability outcomes as part of the project deliverables, which would be an advantage as sustainability continued to increase in importance.

Another interesting observation in this context of measuring project sustainability is that "there are a number of different methods to assess the sustainability of buildings, but not that of a business project in the construction industry" [68]. This presents yet another motivation towards further research so that in time, evaluating project sustainability could become as prevalent as risk assessment and mitigation in projects. This is likely to be more of a lobbying thrust, probably best suited to project management institutes and organizations, and possibly also government bodies.

Finally, echoing the quote at the beginning of this section [69], evaluating sustainability is only one half of the equation—the other half is how to remedy a project that is not up to the required sustainability standard. This is the domain of tactics and solutions to improve sustainability in construction projects. As is alluded to later in the paper, this is also a field of research that is ripe for further investigations.

4.6.2. Project Management for Sustainability

The second set of keywords that is discussed are those linked to Cluster 2—project management for sustainability. One of the main issues with applying sustainability to project management is the perception of an inherent tension. For example, the need for sustainable projects to mitigate the effects of climate change could be seen to be in conflict at a macro and microeconomic level. At the macroeconomic level, it is the requirements to use construction projects to grow economies. At the microeconomic level, it is the need for rapid and affordable reconstruction to repair damage caused by events, such as floods and bushfires. In both cases, the materials and methods might not be environmentally sustainable but the need for the construction project and the lack of alternative materials (for example to cement) outweigh concerns linked to sustainability. The keyword co-occurrence analysis of cluster 2—Project management for sustainability shown in Figure 7 below, illustrates the relative prevalence of project management, sustainability, and construction, alongside the environmental constraints that construction projects would encounter, including environmental sustainability, waste management, lean construction and capability. Practical case studies often report on sustainable construction project management within individual locations [68,76] and support findings of other research that highlights tensions with practitioners who perceive sustainable long-term objectives to be at odds with the short-term objectives from construction projects [77].

In essence, many pertinent issues for sustainable construction project management were already identified but the inter-dependencies, influences, and impacts are yet to be fully understood. What Figure 7 is not able to address is whether these are complicated, complex, or both. This is not surprising. Project management researchers already noted how the concept of sustainable project management is problematic. According to [77,78], it is at the intersection of sustainability and project management, and that while there is broad consensus about the meaning of the terms 'project' and 'project management' there is less agreement on the meaning of the term 'sustainability' in the context of a project [67]. This tends to limit a convergence of views between academics and practitioners [77,79] leaving a gap that is filled by opinions and personal values. This can also manifest itself through tensions linked to responsibility, control, and processes in the project. If these tensions were resolved, they "would assist the alignment between educational outcomes and practices to increase project success" [80]. It follows that this lack of convergence and the tensions could be affected by individual motivations. If different motivations underpin this lack of convergence, both academic research and the applied project management discipline might not be met for some time yet. One solution might be to identify the underpinning motivations to better understand the role they play in interpreting what sustainability means in the context of a project [77,81]. Such an approach would necessarily extend beyond project managers, as different project actors can shape the success of projects [82]. Examples include project clients and sponsors, corporate entities, and a wide range of project stakeholders. All can hold values that might motivate them to act in a different way to the project manager. Thus, the source of motivations causing differences in views could be influenced by corporate strategies, including fiscal and economic goals [77,83–85], and the ability of some stakeholders to contribute or withhold resources [73,86,87]. At present, beyond acknowledging that no convergence exists in defining sustainability within a project, the existing literature is yet to develop the construct further.

Some project management researchers sought to provide insight into sustainable project management by examining related practices, such as corporate sustainability including compliance reporting [88–90] and adherence to sustainable principles through triple bottom-line reporting against economic, ecological, and social factors [72,73]. In a recent paper, this concept was developed by exploring the important role played by stakeholders in sustainable projects in ensuring that the triple bottom line was integrated into the project [91]. Their study did not, however, address the tension between the classic economic project constraints of time, cost, and scope [92] nor the longer-term views required to adopt sustainable practices [84]. This supports the notion of tensions where some objectives last only for the life of the project, others last longer, once the life of the product was considered, and the longest focus on global long-term environmental challenges. In effect, all these issues underpin sustainable project management [93]. Recently, two important summaries of the history and boundaries of project management literature about sustainability were published. The first was a literature review [78] that identified the importance of local embeddedness and institutional demands, when undertaking sustainable projects. This creates connections with the project stakeholder theory [86]. However, the review of [78] was conducted through the lens of the rethinking project management school [94], which continually challenges the linear concept of project management processes in general use by many practitioners [95,96]. According to [97], some practitioners eschew such approaches and prefer to use more traditional processes and tools to deliver sustainable projects. It could be that using this lens obscured some more fundamental applied sustainable project management issues that were contained in the paper. More recently, a second review was published that adopted a more classical approach in which researchers summarized narratives in the literature by examining what, how, and why sustainable project management elements are reported [77]. They concluded that many projects cite improvements in economic performance or reputational issues as reasons for adopting sustainable project management and considered these as motivations for integrating project management and sustainability. While both reviews reflected the journey travelled by sustainable project management, they too were relatively silent as to where sustainable project management could be applied. This was somehow addressed by exploring future directions that could inform new sustainable project management research themes [80]. Their research confirmed that academic studies looked at the baseline for research into sustainable project management but that research themes are yet to be developed for examining solutions and embedded maturity. This supports the contention that there remains a lack of convergence of the literature regarding the nature of sustainability within sustainable project management, which creates a gap currently filled by interpretations motivated by the views and values of central actors. The nature of these values mean that the balance between project constraints and sustainability’s environmental, social, and economic concerns likely differ in practice, and consequently, sustainable project management is currently being shaped in different ways.

4.6.3. Drivers of Sustainable Construction

The final set of keywords that are discussed are those arising from Cluster 3—drivers of sustainable construction. From this, the research team found that the existing literature shows that lack of information about sustainability while conducting a construction project especially in developing countries, is a major issue that impacts the success of the project [98]. Although the construction industry provides the infrastructure and establishments for other industries to operate and prosper, it imposes significant pressure on natural resources all over the world. Sustainability means different things for different people. This vagueness in terms of definitions might account for why there are no "one-size-fits-all" descriptions for sustainability [99]. Therefore, identifying the principles of sustainable development in the construction industry and highlighting the drivers/enablers and challenges/barriers to sustainable construction projects is essential. As Figure 8 depicts, sustainability in the construction industry depends on many factors such as proper project management methodologies, the complexity of the project, the level of innovation implemented in managing the project, deploying information technology applications, and so on.

The sustainability performance of construction projects needs to measure the balance between social and economic development, and environmental sustainability. However, the environmental aspects of sustainability are more noticeable than other dimensions in a construction project [37]. While the construction industry in every nation or region has its capacities and shortcomings to deal with sustainability, lack of reporting of sustainability in the valuation process prevents more investment in sustainability [100]. Even in developed countries such as the UK, many construction companies do not report on sustainability practices, implying that office-based and site-based employees adopt a shallow learning approach toward sustainability [101]. Lack of knowledge about sustainability, limited research on how to improve sustainability, technological deficiencies, and culturally less valued practices are barriers that influence sustainability in construction [102]. In addition, while a large portion of barriers is related to the limited awareness of sustainable practices, lack of top management support and lack of legal enforcement by the government are considered as barriers to sustainable construction in developing countries [103]. A semi-structured interview of 25 experienced project managers in Nigeria found additional barriers to sustainability in construction such as perceived high cost, limited transfer of know-how, unclear instructions on implementing sustainability, client requirements and specifications, resistance to change, errors in initiating the sustainable construction, and limited infrastructures and facilities [99]. Although many studies analyzed the impacts of macro-level sustainable strategies and technological advancement on increasing energy efficiency and recycling natural resources, the impacts of individual behavior on the sustainability performance of construction projects at the micro-level was also investigated [104]. They claimed that the sustainability performance of construction projects needed to be measured against "relationship sustainability", along with the iron triangle of time, cost, and quality. They studied the role of project citizenship behavior, including "helping behaviour, project-based compliance, taking charge, and personal initiative" on the sustainability performance of construction projects and uncovered significant direct correlation among them. Therefore, individual behavior and interpersonal relationships of construction project team members promote the sustainability performance of projects, especially when most technical indicators are not sufficient to accomplish the sustainability performance goal. On the other hand, project citizenship behavior of team members in more complex projects tend to influence the sustainability performance of the project more, as compared to the less complex projects [104].

Besides the behavioral characteristics of project team members, other factors drive the environmental sustainability performance of construction projects. Overall, these drivers try to encourage construction firms and projects to adopt practices to use more renewable resources during constructing a project, whilst minimizing waste disposal and pollution. In some cases, drivers of sustainability are mixed with goals of sustainability because they are often interconnected [105]. Notably, the drivers represent the factors that force/push firms towards integrating and implementing sustainability into construction projects, while goals are the outcomes that companies desire to achieve through practicing sustainability into their projects [58]. Presumably, environmental challenges such as the limited natural world, ever-increasing energy prices [106], demanding stakeholders, and stricter environmental regulations [107] act as the drivers of sustainability. However, financial gains, sustainable environment [108], competitive advantage, and green reputation [109] could be considered as some goals of implementing sustainability in practice. A list of 31 drivers of environmental sustainability includes implementation of international standards organization (ISO) 14000 certification [109], the tendency of customers to pay for green designs, knowledge of environmental impacts, implementation of the environmental management system (EMS) [110], comfort and welfare of employees [111], improved energy efficiency, decreased whole lifecycle costs [112], creating new marketing opportunities, and strengthening partner relationships [113].

Clearly, achieving environmental and social sustainability brings economic benefits as well. While indicators such as financial benefits and reduced life-cycle costs are dealt with as the drivers of environmental sustainability, at the same time, they could be considered to be the economic outcomes of implementing sustainability practices in construction projects.

Regarding social sustainability in the construction industry, some organizational internal drivers influence social sustainability performance [114]. Based on the resource-based view (RBV) to better understand the firm-level development with resources, they investigated the relationships between a construction firm and its natural environment, through continuous improvement of its operations, to achieve social and environmental sustainability. Business innovativeness is regarded as a driver of social sustainability, as it helps firms to move from the present technological standpoint to a more sustainable status [114]. Technology orientation is another driver of social sustainability in construction projects [114] because companies with higher technological orientation can better respond to social issues, employees' quality of life and welfare, and expectations of the clients particularly, when they quest for better products at lower costs [115]. In addition, the corporate social responsibility (CSR) activities of contractors both on-site and within the project communities [116] and organizational capabilities, are necessary for firms to face the sustainability-related challenges and pressures imposed [117]. Organizational capabilities significantly improve social sustainability performance, directly or indirectly, through technological orientation. Therefore, construction companies are expected to strengthen their organizational capabilities, foster essential capacities to improve business innovativeness, and upgrade and adapt to emerging advanced technologies to boost their social sustainability performance [114].

5. Conclusions and Future Research Directions

The increasing importance of sustainable construction project management could be viewed from many different angles. Construction projects can be mega projects that are needed for continued economic growth, but that might not be environmentally sustainable due to the intended use of the final product or the materials used in the project. While mainly funded by governments, they are usually intended to spur commercial growth, which in turn, often leads to smaller scale construction projects. Both government and commercial construction projects put the project manager at the heart of decisions regarding sustainability. This is, in effect, adding another constraint to time, cost, quality, and scope. Our research showed that this is largely absent from existing project management frameworks. What this current research exposed is the complicated relationships within sustainable construction project management, and these might also be complex relationships or could be both complicated and complex. Further research into the complicated and complex interrelationships inherent in sustainable construction project management could provide additional valuable insight. In this context, there are therefore some main areas where further research would be a significant contribution to our knowledge:

- The development of a single or dominant system to evaluate sustainability in projects.

- The extent to which it is possible to increase sustainability evaluations in projects, aiming to make this as common as risk assessment and mitigation in projects.
- The identification of a range of remedies, tactics, and solutions that are highly effective at improving sustainability in projects.
- The evaluation of project success looking at the interrelations among project sustainability factors.
- Investigating the mutual relations between sustainability and benefits management in the construction industry.
- Comparative analysis of sustainability in construction projects in developed and developing countries.

In addition, the lack of convergence between academics and practitioners about the nature of sustainable construction project management also requires further study. Without this, the construction project manager might continue to be the academic focus for solutions to sustainable construction project management dilemmas, despite not having the knowledge, authority, or capability to influence sustainable outcomes. Deep analysis and synthesis of the shortlisted papers in this study revealed three major research streams—(a) evaluating sustainability, (b) project management for sustainability, and (c) drivers of sustainable construction. Provided the contributions of this study in determining the research foci and analyzing their co-occurrence, this study faces two limitations. We reviewed the papers published from 2015 to 2020. While this short period revealed major research streams, reviewing more documents certainly provides a better picture of sustainability in construction projects. Sustainability might have different implications in terms of the size of the construction projects. Future studies, therefore, are recommended to separately investigate the impacts and implications of sustainability in small, medium, and large construction projects.

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