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A Scientometric Analysis and Systematic Literature Review for Construction Project Complexity

Hassan Ghaleb [1], Hamed Hamdan Alhajlah [2], Abdul Aziz Bin Abdullah [1], Mukhtar A. Kassem [3,*] and Mohammed A. Al-Sharafi [4,*]

[1] Faculty of Business and Management, Universiti Sultan Zainal Abidin, Kuala Nerus 21300, Terengganu, Malaysia; hassan.alolofi@gmail.com (H.G.); abdulazizum@gmail.com (A.A.B.A.)
[2] Civil Engineering Department, Faculty of Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, West Midlands, UK; hxa580@alumni.bham.ac.uk
[3] Department of Quantity Surveying, Faculty of Built Environment & Surveying, University of Technology Malaysia (UTM), Johor Bahru 81310, Johor, Malaysia
[4] Department of Information Systems, Azman Hashim International Business School, University of Technology Malaysia (UTM), Skudai 81310, Johor, Malaysia
* Correspondence: mukhtarkas@gmail.com (M.A.K.); alsharafi@ieee.org (M.A.A.-S.)

Abstract: The construction industry has been experiencing a rapid increase in complex projects for the last two decades. Simultaneously, project complexity has received more attention from academics and practitioners worldwide. Many studies suggest that perceiving complexity is critical for successful construction project management. This study investigates the current status and future trends in construction project complexity (CPC) literature from the Scopus database. This review systematically uses bibliometric and scientometric methods through co-occurrence and co-citation analysis. First, 644 academic documents were retrieved from the Scopus database. Then, co-occurrence and co-citation analysis were performed along with network visualization to examine research interconnections' patterns. As a result, relevant keywords, productive authors, and important journals have been highlighted. The prominent research topics within the literature on construction project complexity focus on the following topics: identifying and measuring project complexity, schedule performance and cost estimation, system integration and dynamic capabilities, and risk assessment and uncertainty. Finally, the potential research directions are developing towards safety performance, organizational resilience, and integrated project delivery (IPD). The study still has a limitation. The review focuses only on the academic documents retrieved from the Scopus database, thus restricting the coverage of the reviewed literature relating to construction project complexity. To the best of the author's knowledge, this study is the first study that provides a systematic review of the literature from the Scopus database on construction project complexity.

Keywords: construction project complexity (CPC); systematic literature review (SLR); bibliometrics; scientometric analysis (BSA)

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1. Introduction

Complexity theory was initially introduced to the knowledge of project management by [1–8]. All these studies have emphasized the impact of complexity on projects, particularly on project goals, organization structure, and required management experiences and it is widely recognized that complexity has significant effects on the project management process such as: (i) complexity affects project coordinating, planning, and controlling, (ii) complexity causes difficulties identifying primary project goals and objectives, (iii) complexity is an essential factor in forming the suitable organizational structure and selecting project team with proper level of experience, (iv) complexity is a selection criterion for adequate arrangement in project management; and (v) complexity directly influences the main project's outcomes such as cost, time, quality, and safety. Perceiving and grasping project complexity is very important for project managers to effectively make decisions and achieve goals related to complexity [8,9]. While complexity is increasing in projects, conventional project management practices have become ineffective. Therefore, the project complexity concept has received more attention from scholars and practitioners [1,8]. It is undeniable that project organizations are suffering failure due to increasing complexity; however, it is not apparent how this phrase is correct. Therefore, describing complexity from different aspects and a better understanding of complexity management can benefit worldwide project management communities [10]. Complexity affects projects negatively due to ambiguity and emergencies that are associated with the dynamic characteristics of the entire system. Project managers need to manage complexity and know-how to prevent emerging opportunities to reduce or avoid the negative impact of complexity [11].

This study aims to use bibliometric and scientometric analysis to answer the following research questions:

RQ1. What are the most relevant keywords in construction project complexity studies?
RQ2. Which are the most important journals and productive authors on construction project complexity studies?
RQ3. What are the most prevalent themes of construction project complexity between scholars?
RQ4. What are the future trends of publications on construction project complexity studies?

This review study aims to better understand project complexity, especially in its increasing global construction industry. This study will also assist researchers in proposing future research recommendations by examining the Scopus database publications on construction project complexity. A scientometric analysis is defined as a "quantitative study of science, communication in science and science policy" [12]. The scientometric analysis involves assessing the research effect, exploring the impact of academic journals and research institutions in a particular area of knowledge, and includes analysis techniques for citation inter-relationships [13]. Recent research in the construction field, such as construction engineering and management (CEM) and building information modelling (BIM), are employing scientometric methodology [14]. This paper presents a systematic review using the scientometric approach to analyze and map the literature on construction project complexity (CPC). The findings of this paper identify the main topics in the literature on complexity and provide a better understanding of current research directions. This paper has been divided into four sections containing methodology, findings and interpretations, a discussion of various considerations and problems elaborate in answering the research questions, and finally, the conclusion.

2. Research Methodology

Academic publications relevant to construction project complexity (CPC) have been retrieved from the online dataset to fulfil this review study's objectives. Thus, a list of academic publications was extracted from the Scopus database. To overcome the difficulty of searching every related article, drawing the borders of the research area is essential [15]. In this paper, a systematic methodology is employed, a science mapping approach is adopted to perform bibliometric and scientometric analysis based on the Scopus online database as a source of data. Figure 1 shows the methodological process framework for this study.

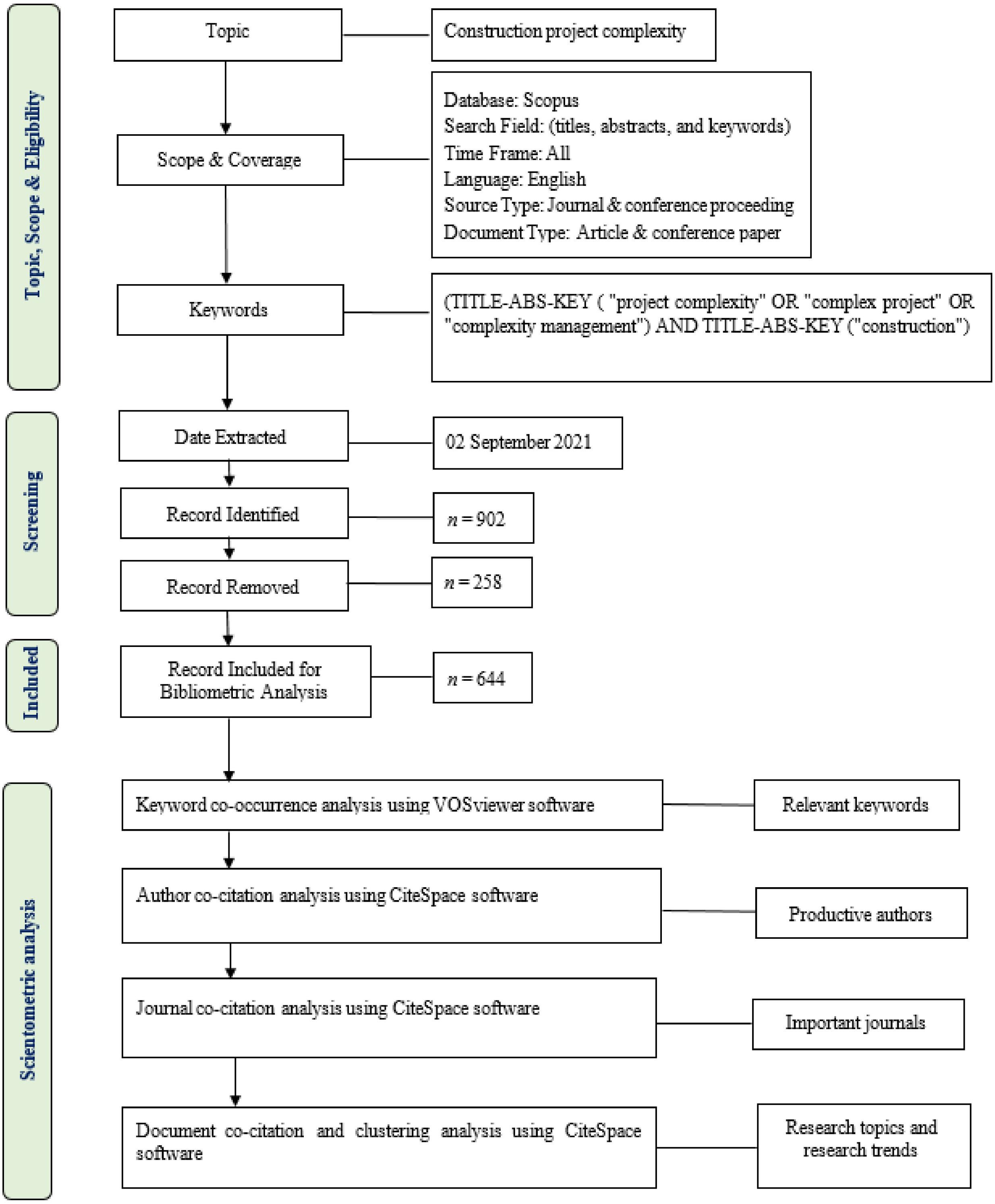

Figure 1. Flow diagram of the search methodology.

2.1. Bibliometric Analysis

Bibliometric search retrieves data for required documents that have an academic structure [16,17]. Scopus is one of the most comprehensive database sources [18]. The Scopus database provides the broadest documents coverage over other databases [19,20]. Therefore, the Scopus database is selected in this paper to review the current literature on project complexity in the construction industry. Additionally, the Scopus database covers the most recently published documents [21,22]. The Scopus database is one of the most important peer-reviewed literature sources, including the highest citations and abstract numbers [18,23]. The Scopus database is selected for this review paper because it has the widest coverage of construction-related academic research compared to other databases such as Google Scholar, Web of Science, and PubMed [19]. Furthermore, the Scopus database contains the widest range of peer-reviewed journals [24]. For a comprehensive literature review, articles related to project complexity in the construction industry were retrieved using the following keywords: ("project complexity" OR "complex project" OR "complexity management") AND ("construction") and a search conducted within the code of (titles, abstracts, and keywords). The research subjects were limited to Engineering, Business Management and Accounting, Decision Sciences, Social Sciences, Economics, Econometrics and Finance, and Multidisciplinary, which are related to the construction domain. Only English journal and conference proceedings papers were selected for this review. Research query was carried out on 2 September 2021 with following final string: (TITLE-ABS-KEY ("project complexity" OR "complex project" OR "complexity management") AND TITLE-ABS-KEY ("construction")) AND (EXCLUDE (SUBJAREA, "EART") OR EXCLUDE (SUBJAREA, "ENER") OR EXCLUDE (SUBJAREA, "ARTS") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "CENG") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "AGRI") OR EXCLUDE (SUBJAREA, "CHEM") OR EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "HEAL") OR EXCLUDE (SUBJAREA, "PSYC") OR EXCLUDE (SUBJAREA, "IMMU") OR EXCLUDE (SUBJAREA, "NURS") OR EXCLUDE (SUBJAREA, "PHAR")) AND (EXCLUDE (SRCTYPE, "d") OR EXCLUDE (SRCTYPE, "k") OR EXCLUDE (SRCTYPE, "b") OR EXCLUDE (SRCTYPE, "r")). The other screening process was conducted by reviewing documents' titles and abstracts to identify only papers related to the area of construction project complexity. After a careful manual filtering process, the remaining documents in the final dataset are 644 documents, including 379 journal articles and 265 conference papers.

2.2. Scientometric Analysis

The scientometric analysis is defined by [25] as "a quantitative study of the research on the development of science." It is a technique to evaluate research impact and investigate citation relationships to map a specific knowledge area with trends extracted from the academic database. The manual literature review can lay out a comprehensive mapping of a particular research area; however, it remains subjected to bias and limited to subjective interpretation [26]. Therefore, the scientometric technique, used in this study to analyze project complexity within the construction domain, is adopted as an approach for visualizing and mapping the knowledge area [27]. The scientometric method uses bibliometric data to generate a network model and identifies research subjects [28]. The scientometric analysis generates network models to visualize the intellectual view of a specific knowledge area that can assist researchers in answering their questions and achieving research objectives [29]. Network visualizing the field of construction project complexity will assist researchers in perceiving the overall research patterns and discovering the research trends.

Abstract and keywords concisely represent the content of publications. Consequently, keywords are used as a unit of analysis to establish clusters reflecting the prominent components of the research area. In this review paper, a bibliometric search was performed using the title, abstract, and keywords code for a comprehensive literature review of construction project complexity. The following analysis was conducted to disclose the research pattern: keyword co-occurrence analysis, author co-citation analysis, burst identification, journal co-citation analysis, and document co-citation and clustering analysis. Keyword co-occurrence and author co-citation analysis provide a general description of the research area before clustering analysis. Burst assists in identifying research behaviour over time and navigating recent construction project complexity trends. Document co-citation analysis provides clustering techniques and labels clusters with abstract terms to lay out the research areas. This approach has been suggested previously for systematic literature review [30,31].

3. Results and Findings

3.1. Data Acquisition

Academic documents, journals, and conference papers related to construction project complexity were extracted using the keyword search strategy from the Scopus database. The Scopus database allows to browse and sort required documents by subject area, and statistics are displayed as 47.7% related to engineering and 22.9% related to business and management, as shown in Figure 2.

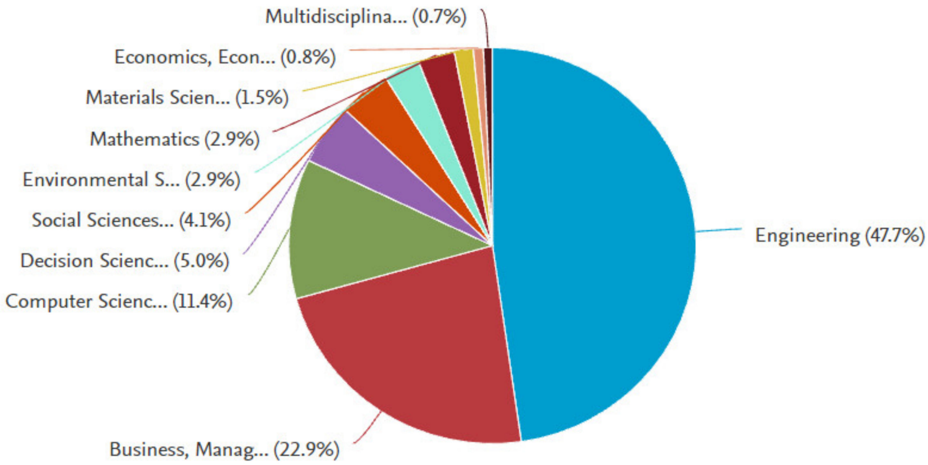

Figure 2. Documents by subject area.

Figure 3 shows the number of published documents each year. Publications in construction project complexity exhibit an upward trend between 2006–2017, and the highest number of publications were in the years of 2017 and 2019 with published documents of 56 and 51, respectively. Although, notably, this study covers publications for only 9 months of the year 2021, records in 2021 would be estimated at around 50 publications if linear regression is applied to extend the statistical graph.

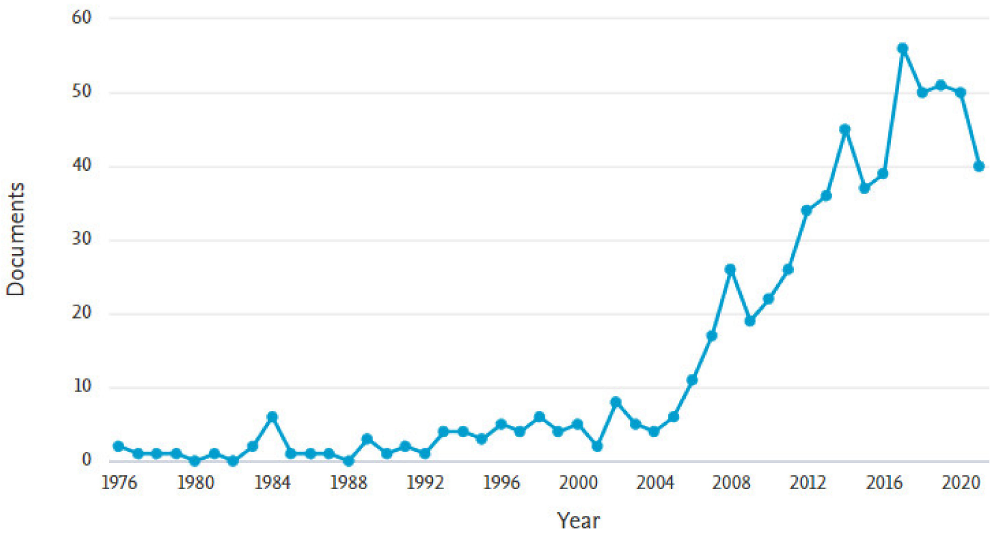

Figure 3. Documents by year of publication.

3.2. Keyword Co-Occurrence Analysis

Keywords are words or phrases that reflect overall document content and express the researched area inside the domain boundaries [32]. In this study, VOSviewer software performs keyword co-occurrence analysis and creates networks based on the data from the Scopus database. Generated map is a distance-based network, and the space between nodes indicates the strength of the relationship between the keywords [33]. The closer distance between nodes generally represents the more robust relationship between the keywords, and node size is directly proportional to the number of documents containing that keyword. VOSviewer tool provides a clustering technique to set related keywords in the same group with the same color [34]. Only keywords with high-occurrence numbers are selected to map the network, so the threshold was set at 5, and 41 keywords remain from 1513 total keywords. Figure 4 shows a keywords co-occurrence network with 41 nodes, 153 links, and total link strength of 236. Table 1 summarizes the most frequent keywords with their occurrences and the mean year published, links, and full link strength.

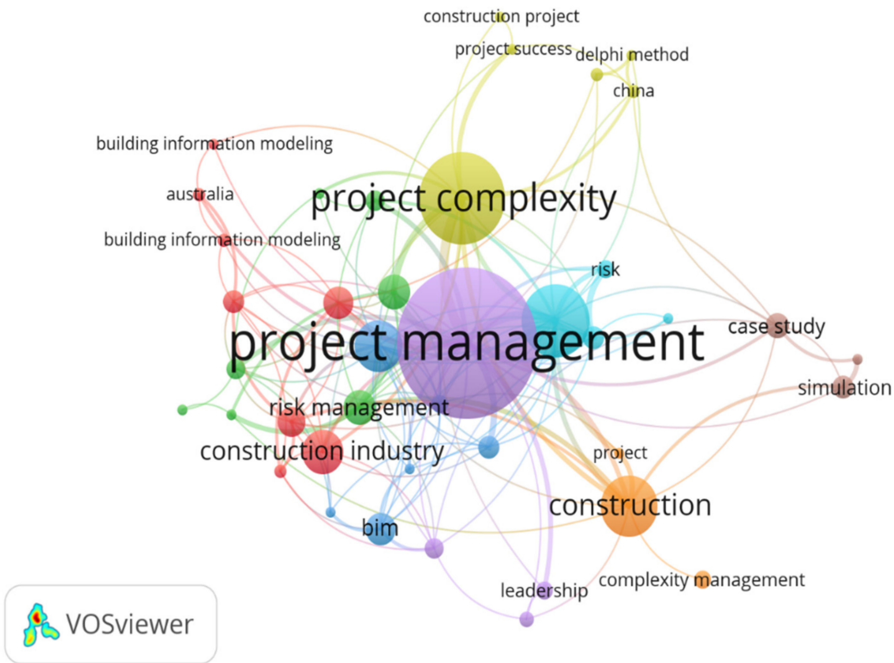

Figure 4. Keyword co-occurrence network.

Table 1. Selected keywords with network parameter.

Keyword	Occurrences	Mean Year Published	Links	Total Link Strength
Project management	64	2013	27	42
Project complexity	39	2015	18	25
Complexity	31	2013	20	21
Construction	26	2014	12	18
Risk management	15	2015	13	13
Construction industry	19	2013	9	11
Construction management	22	2014	15	11
Complex projects	14	2014	11	10
Construction projects	15	2017	9	10
Procurement	13	2014	10	10
Uncertainty	10	2014	10	9
Collaboration	10	2016	10	8
Project performance	9	2016	9	8
Scheduling	10	2015	9	8
BIM	14	2015	9	7
Case study	11	2013	8	7
Communication	9	2013	5	7
Lean construction	9	2015	9	7
Innovation	8	2017	11	6
Risk	8	2010	5	6

Table 1. *Cont.*

Keyword	Occurrences	Mean Year Published	Links	Total Link Strength
Simulation	10	2010	4	6
China	6	2013	6	5
Partnering	6	2014	6	5
Project	5	2015	3	5
Risk identification	5	2013	4	5
Design management	5	2014	6	4
Integration	5	2011	5	4
Leadership	8	2012	3	4
Productivity	7	2010	4	4
Project success	5	2016	4	4
Systems thinking	5	2016	4	4
Tunnel construction	5	2015	2	4
Australia	6	2015	4	3
Building information modelling (bim)	6	2018	4	3
Delphi method	5	2013	3	3
Design-build	6	2015	4	3
Building information modelling	5	2013	3	2
Construction project	5	2017	2	2
Knowledge management	5	2013	2	2
Management	5	2014	3	2
Complexity management	8	2015	1	1

According to VOSviewer statistical technique, Table 1 shows the term (project management) is the most frequent author keyword in the literature, and the word (project complexity) is the second. However, the word (project complexity) is mentioned implicitly in different phrases such as project complexity, complexity, complex projects, and complexity management. Aggregating frequencies of those items will result in 92 occurrences. Thus, the term (project complexity) can be considered the most mentioned author keyword in the literature, and the word (project management) will be the second. The mean year of publication indicates the average period researchers have used this keyword in their documents. For instance, documents that include scheduling received more attention in 2015, while publications that include risk, integration, and uncertainty have received more attention in 2010, 2011, and 2014. The links represent the number of connections between a particular node and other nodes, while the total link strength represents the overall strength of the links connected to a given node [35]. For example, the entire link strength of the keyword (project management) is 42, which is the highest among other nodes and suggests the strongest inter-related keyword to project complexity.

3.3. Author Co-Citation Analysis

The CiteSpace tool can analyze and visualize a scientific research field to logically perceive a cohesive and organized knowledge structure. This method is widely recognized as a practical scientometric approach to disclosing concealed implications from an enormous amount of information. Moreover, CiteSpace is a powerful tool in mapping the knowledge area and systematically generates various network maps [36]. Therefore, this systematic review adopts CiteSpace to create a co-citation network and perform abstract clustering analysis. Kleinberg developed CiteSpace in 2003, and a burst detecting algorithm is added to the application.

The author co-citation network presents the relationship between authors whose publications are cited in the same document. Figure 5 shows the author's co-citation network, including 475 nodes and 3604 links. As recommended in earlier studies, network pruning was carried out through the pathfinder function to remove unnecessary links [37]. Thus, node size represents each author's co-citation frequency, and connections between nodes reflect citation relationships created by the number of citations. The top-ranked author is (Anonymous) with citation counts of 60. The second one is (Baccarini D), with citation counts of 56. The third is (Williams TM) with citation counts of 34. The 4th is (Flyvbjerg B) with citation counts of 29. The 5th is (Bosch-Rekveldt M) with citation counts of 27. The 6th is (Chan APC) with citation counts of 24. The 7th is (Love PED) with citation counts of 21. The 8th is (Geraldi J) with citation counts of 19. The 9th is (Williams T) with citation counts of 18. The 10th is (Dao B) with citation counts of 17. Authors with the most robust citation bursts, who received a sudden increase in the number of citations during a short time, are identified and sorted as shown in Figure 6.

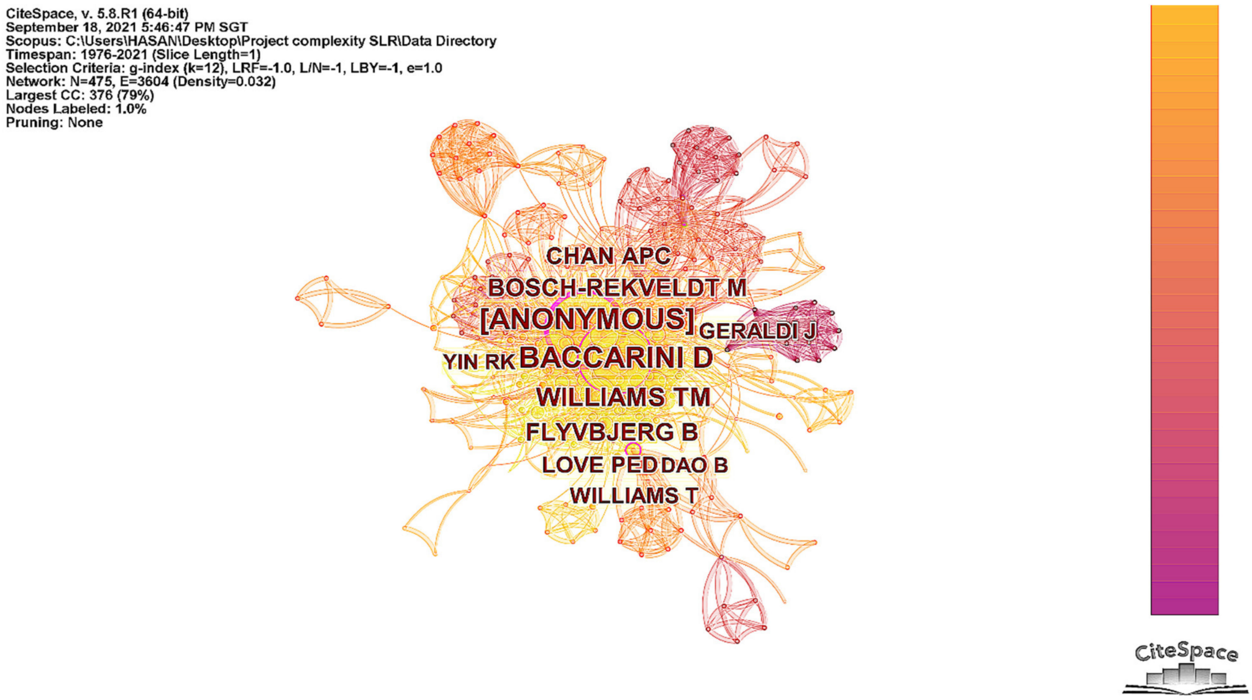

Figure 5. Author co-citations network.

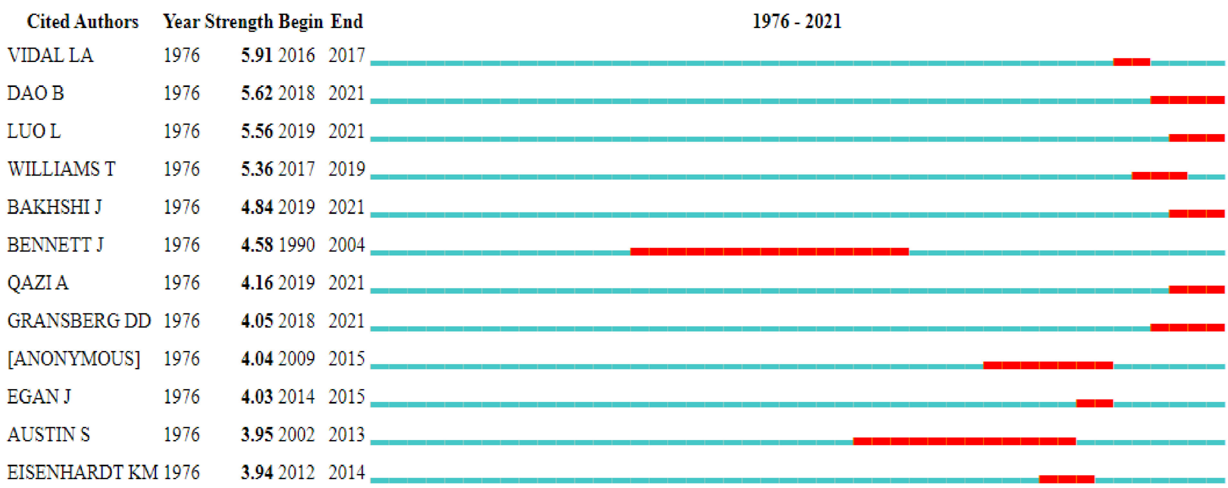

Figure 6. Authors with the strongest citation bursts.

Additionally, information about authors can be obtained from bibliometric records, and the most productive authors in the field can be identified by Scopus analysis. For example, Figure 7 shows the top leading researchers in construction project complexity Kermanshachi, S (The University of Texas); Zhang, L (Nanyang Technological University); and Skibniewski, M. J. (University of Maryland) are holding the top three positions.

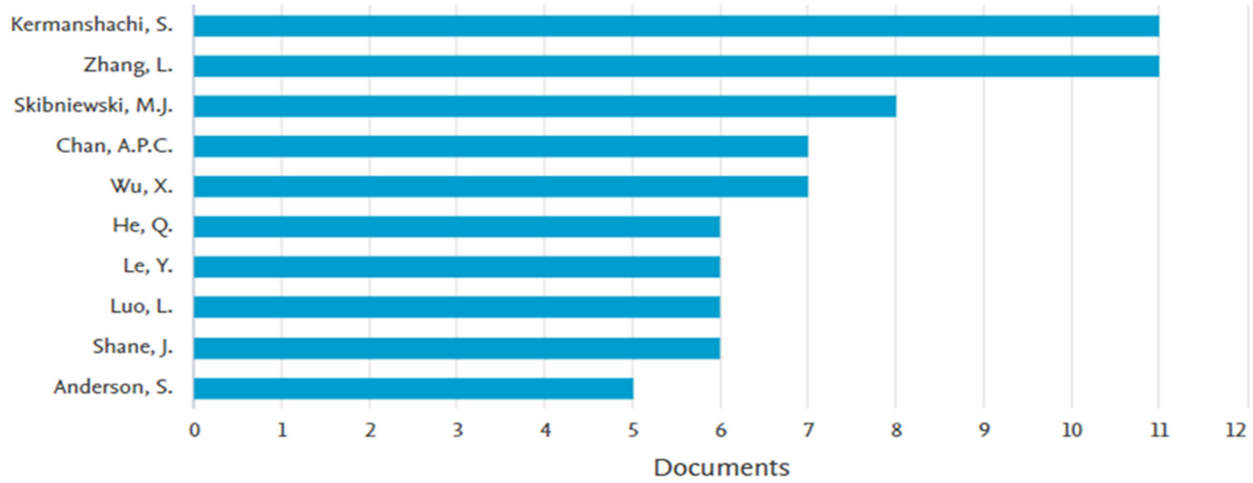

Figure 7. Productive authors in construction project complexity.

3.4. Journal Co-Citation Analysis

Table 2 shows the list of top sources (journals and conference proceedings) of academic documents related to construction project complexity.

Table 2. Top sources of academic documents of construction project complexity.

Journal Title	Relevant Published Articles	% Total Publication
Journal of Construction Engineering and Management	33	8.71%
Engineering Construction and Architectural Management	24	6.33%
Journal of Management in Engineering	22	5.80%
International Journal of Project Management	16	4.22%
Construction Management and Economics	15	3.96%
Automation in Construction	12	3.17%
International Journal of Managing Projects in Business	10	2.64%
Journal of Civil Engineering and Management	8	2.11%
Journal of Computing in Civil Engineering	8	2.11%
Construction Economics and Building	6	1.58%
International Journal of Construction Management	5	1.32%
Construction Innovation	4	1.06%
Journal of Professional Issues in Engineering Education and Practice	4	1.06%
Proceedings of the Institution of Civil Engineers Civil Engineering	4	1.06%
Advanced Engineering Informatics	3	0.79%
Built Environment Project and Asset Management	3	0.79%
Computers and Industrial Engineering	3	0.79%
Facilities	3	0.79%
IEEE Engineering Management Review	3	0.79%
International Journal of Project Organisation and Management	3	0.79%
Journal of Financial Management of Property and Construction	3	0.79%
Journal of Information Technology in Construction	3	0.79%
Proceedings of Institution of Civil Engineers Management Procurement and Law	3	0.79%
Production Planning and Control	3	0.79%
Project Management Journal	3	0.79%
Conference Title	**Relevant Published Articles**	**% Total Publication**
IOP Conference Series Materials Science and Engineering	11	4.15%
Procedia Engineering	10	3.77%
Proceedings Annual Conference Canadian Society for Civil Engineering	10	3.77%
ISEC 2013 7th International Structural Engineering and Construction Conference New Developments in Structural Engineering and Construction	5	1.89%

Table 2. *Cont.*

AACE International Transactions	4	1.51%
Construction Research Congress 2016 Old and New Construction Technologies Converge in Historic San Juan Proceedings of the 2016 Construction Research Congress CRC 2016	4	1.51%
Proceedings 30th Annual Association of Researchers in Construction Management Conference ARCOM 2014	4	1.51%
22nd Annual Conference of The International Group for Lean Construction Understanding and Improving Project Based Production IGLC 2014	3	1.13%
31st International Symposium on Automation and Robotics in Construction and Mining ISARC 2014 Proceedings	3	1.13%
AACE International Transactions of The Annual Meeting	3	1.13%
ASEE Annual Conference and Exposition Conference Proceedings	3	1.13%
ASEE Annual Conference Proceedings	3	1.13%
Association of Researchers in Construction Management ARCOM 2010 Proceedings of the 26th Annual Conference	3	1.13%
Cobra 2008 Construction and Building Research Conference of The Royal Institution of Chartered Surveyors	3	1.13%
Computing in Civil Engineering New York	3	1.13%
Congress on Computing in Civil Engineering Proceedings	3	1.13%
IGLC 2012 20th Conference of The International Group for Lean Construction	3	1.13%
Proceedings of the International Conference on Industrial Engineering and Operations Management	3	1.13%
Understanding and Managing the Construction Process Theory and Practice 14th Annual Conference of The International Group for Lean Construction IGLC 14	3	1.13%

Top sources of academic publications for construction project complexity were identified from the Scopus database statistics and extracted in Table 2. Journals that include the most publications are Journal of Construction Engineering and Management, Engineering Construction and Architectural Management, Journal of Management in Engineering, International Journal of Project Management, Construction Management and Economics, Automation in Construction, and International Journal of Managing Projects in Business. Similarly, conference proceedings that contribute the most to the research field of CPC are IOP Conference Series Materials Science and Engineering, Procedia Engineering, and Proceedings Annual Conference Canadian Society for Civil Engineering.

Journal co-citation analysis using the CiteSpace was carried out, and a journal co-citations network was created with 469 nodes and 3631 links. As shown in Figure 8, the node size represents citation frequency as the most cited journals offer more significant nodes on the network. The top-ranked journal by citation counts is the International Journal of Project Management, with citation counts of 181. The second is the Journal of Construction Engineering and Management, with citation counts of 154. The third is the Journal of Management in Engineering, with citation counts of 93. The 4th is Construction Management and Economics, with citation counts of 89. Finally, the 5th is Automation in Construction, with citation counts of 72. It is noticeable that all the most cited journals are also among the top source journals publishing articles for construction project complexity.

3.5. Document Co-Citation and Clustering Analysis

The document co-citations network assists in mapping the research field and grouping documents based on the citation relationship between publications. In this section, a document co-citation network is created containing 415 nodes and 1275 links, as shown in Figure 9. Each node represents a document, and node size indicates the co-citation frequency. Links between nodes represent the co-citation relationship between publications. Mean silhouette (S) and modularity (Q) are essential metrics given by CiteSpace which determine network structural properties. Modularity is considered high when Q is more than 0.3, indicating the network is separated into loosely coupled clusters [38]. When the silhouette score is more than 0.5, that suggests network clustering is heterogeneous [39].

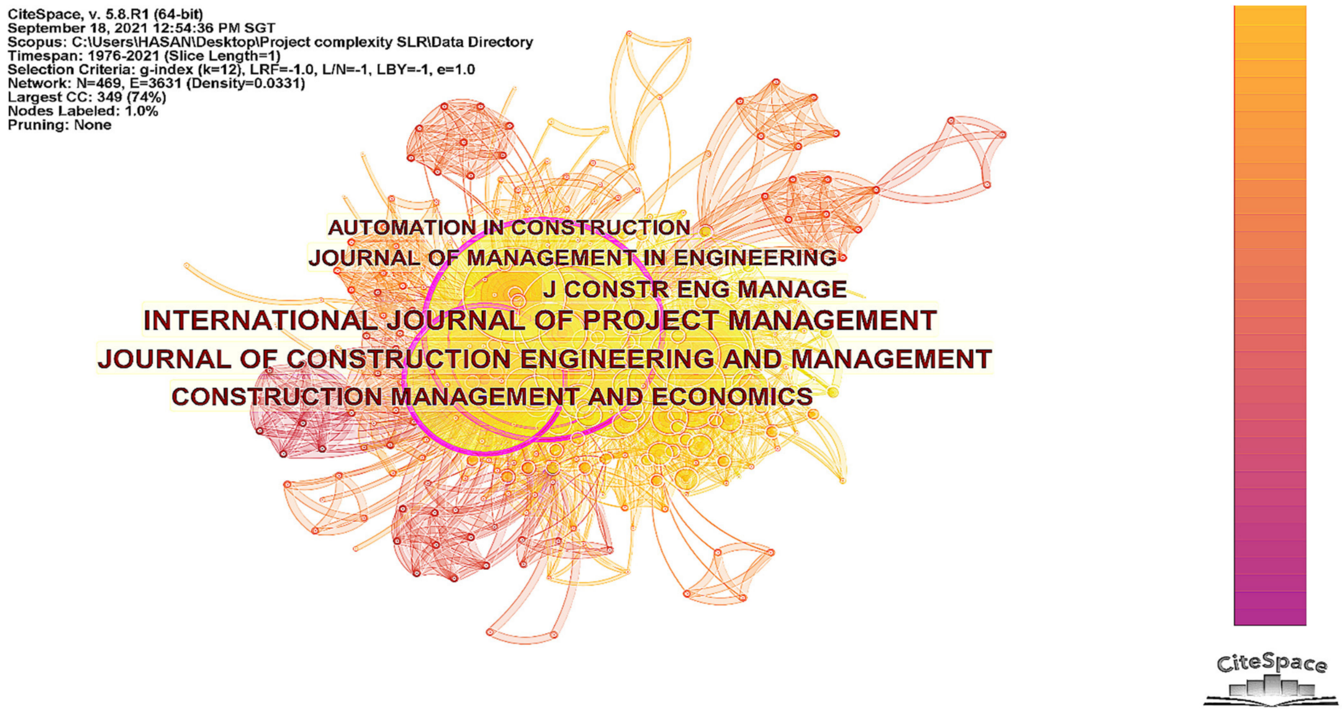

Figure 8. Journal co-citations network.

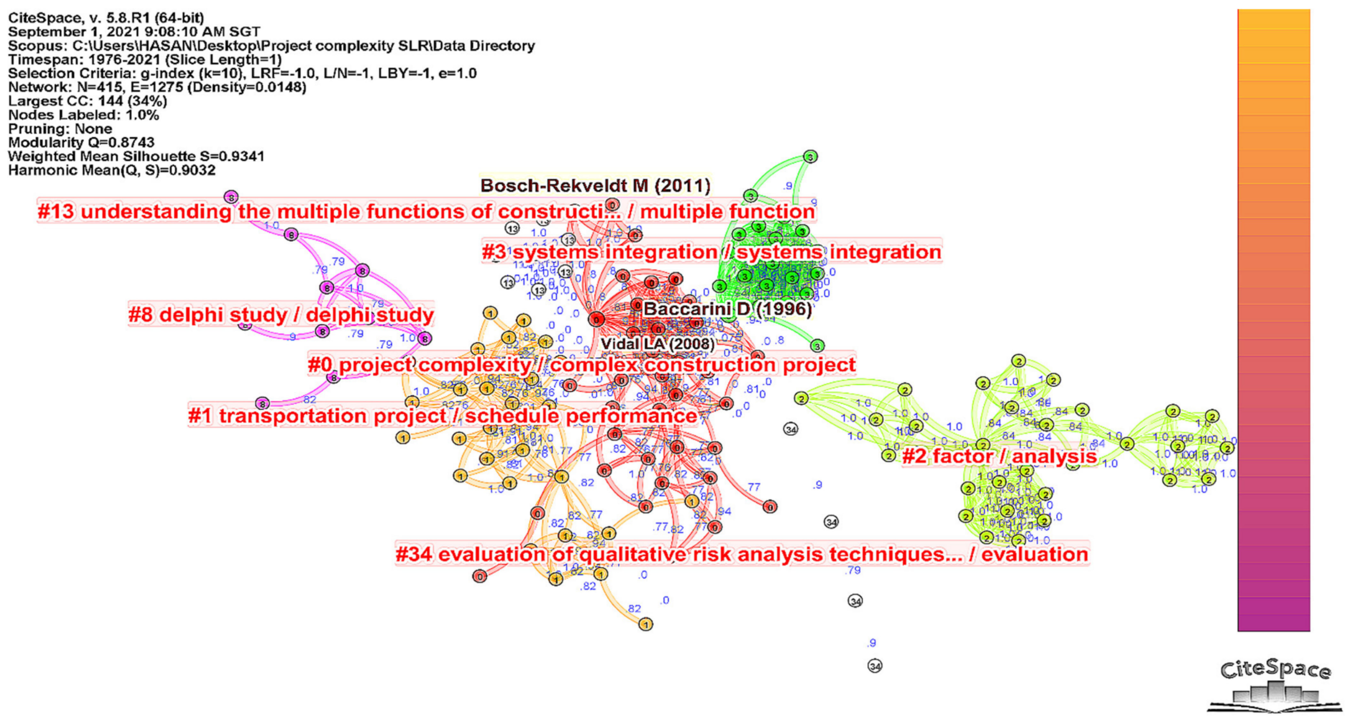

Figure 9. Network of document co-citations analysis.

This study divides the network into seven co-citation clusters at a modularity measure and harmonic mean of 0.87 and 0.90, respectively. LSI/LLR labelling algorithms provided by CiteSpace are employed to tag each set automatically. Identified clusters are loosely linked; however, clusters borders can be recognized. Table 3 summarizes clusters information such as cluster size, mean year, LSI/LLR labels, and the most cited document in each cluster. The log-likelihood ratio (LLR) algorithm allows unique and sufficient coverage for labelling clusters based on the keywords [40].

Table 3. Co-citation clusters analysis of construction project complexity.

Cluster-ID	Size	Mean (Year)	Top Terms (Latent Semantic Indexing) LSI	Top Terms (Log-Likelihood Ratio) LLR	The Most Cited Document
0	41	2006	Project complexity	Complex construction project	[41]
1	30	2003	Transportation project	Schedule performance	[42]
2	29	1985	Factor	Analysis	[43]
3	22	1991	Project complexity	Systems integration	[44]
8	10	2003	Delphi study	Delphi study	[45]
13	8	2006	Understanding the multiple function of construction contracts	Multiple function	[46]
34	4	2001	Evaluation of qualitative risk analysis techniques in selected large construction companies in Nigeria	Evaluation	[47]

4. Research Topics in Construction Project Complexity

This section will discuss the clusters presented in Table 3 and review the most cited documents mentioned in each group. Then, research topics will be analyzed based on the most relevant publication and ordered according to the number of publications in the research areas.

4.1. Identifying and Measuring Project Complexity

Managing project complexity is one of the critical strategies to improve project performance and enhance successful project delivery. Measuring project complexity is a vital practice to manage project complexity in the construction industry. Assessing complexity enables managers to identify difficulties and allocate scarce resources efficiently in complex construction projects. Thus, many research studies were conducted to develop measurement models and evaluate project complexity from different perspectives [48]. Figure 9 illustrates that cluster #0 and cluster #8 are closely located in the networks. From Table 3, cluster #0 and cluster #8 cover the same area of research in measuring project complexity. Cluster #0 is the largest cluster in the network, including 41 publications, while cluster #8 is more minor, containing ten publications.

For cluster #0, the most cited document was published by [41], which developed a complexity measurement model for large-scale construction projects from a task and organization (TO) perspective. Luo et al. [49] analyzed the relationship between project complexity and success in complex construction projects, and the findings prove a negative relationship between complexity and success in the complex construction project. Eriksson et al. [50], suggested that flexible practices are adapted to complex projects for better schedule performance. Accordingly, the model of flexibility focused project management was introduced. Finally, Ahn et al. [51] examined the influence of interface-management practices in large-scale engineering construction projects. The study reveals that IM practices mitigate the negative impact of project complexity that emerges from scope uncertainty, communication, and large numbers of stakeholders.

On the other hand, IM practices are not effective with complexity originating from other engineered items. Sohi et al. [52] developed a practical framework to add flexibility to project management practices. The suggested framework will reduce project complexity and dynamics in the construction industry and improve project delivery success. Nguyen et al. [53] developed a complexity level (CL) measure to evaluate and quantify complexity specifically in transportation projects. Luo et al. [54] created a project complexity measurement model (PCMM) employing a Bayesian belief network-based methodology. This model considers a cause-effect relationship. Thus, complexity can be measured under what-if scenarios for complexity management. Additionally, Nguyen et al. [55] employed a computational model in MATLAB to measure the complexity level in construction projects.

The measure is called complexity level (CL), which quantifies project complexity and foresees general difficulties.

For cluster #8, the most cited document was published by Xia and Chan, [45] which developed a complexity index (CI) based on six key complexity measures. These complexity measures assist stakeholders in evaluating complexity levels and managing associated risks in building projects. Furthermore, in their study, B. Xia and Chan [45] identified that project complexity is one of the top seven selection criteria for operational variations of the construction industry's design-build (DB) system. Finally, Cooke [56] concluded in his study that knowledge and data sharing in construction projects can be enhanced by advanced information management; thus, complexity may well be diminished, and many issues in the early life of the project can be resolved.

For cluster #13, the most cited document was published by Y. Chen et al. [46] and found that project complexity is the most important factor affecting the main functions (control, coordination, and adaptation) of the FIDIC construction contract model.

4.2. Schedule Performance and Cost Estimation

In the history of the construction industry, complexity is the main reason for poor performance and project failure in terms of cost overrun, schedule delay, low quality and even safety issues [57,58].

For cluster #1, the most cited document was published by Nguyen et al. [42] exploring the relationship between project complexity and project performance with resource allocation in construction projects. Findings from the empirical study show that project complexity significantly impacts schedule performance, influenced by resource allocation. Hietajärvi et al. [59] investigated the integration mechanisms to develop throughout complex alliance projects. The study found that adopting different integration mechanisms demands complex and alliance project organizations in response to dynamic situations. Hartono et al. [60] examined the relationship between project risk management maturity (PRMM) and organizational performance with the effect of project complexity as a moderating variable. Results suggested that (PRMM) is remarkable in project-based organizations; however, the significance of (PRMM) diminishes when the project complexity level is low. Project complexity is a considerable variable when setting organizational maturity. Damayanti et al. [61] defined the complexity of the mega-construction project in Indonesia from project managers' perspectives. The study found that project managers perceive complexity as an obstacle and view complexity in mega-construction projects negatively, even though positive opportunities can be associated with complexities. Hietajärvi et al. [62] defined project alliance (PA) capability and identified its components, as PA capability is a vital delivery model for delivering complex projects.

For cluster #2, the most cited document was published by Akintoye [43] which identified factors influencing cost estimating practices in construction projects. The study included eighty-four contractors ranging from very small to huge companies. Factor analysis resulted in classifying factors into seven groups. The project complexity factor is ranked as the most crucial factor affecting construction project costs.

4.3. Systems Integration and Dynamic Capabilities

Complexity has a significant impact on systems integration. Therefore, systems design improvement must be more integrated and flexible, delaying complexity issues [63].

For cluster #3, the most cited document was published by Davies and Mackenzie [44] who found that systems' integration is the major challenge in delivering complex projects. Organizations overcome project complexity by partitioning the project into integrated subsystem components. Organizations have to understand the whole system of components and manage flexible interfaces between individual components to maintain stability in dynamic and uncertain changing conditions. Brady and Davies [64] compared how structural and dynamic complexity was controlled in two successful construction megaprojects. The study revealed differences in the two approaches dealing with structural and dynamic complexity; however, common factors were identified those assist project managers in successful complex projects. Davies et al. [65] emphasizes that particular dynamic capabilities (strategic behaviour and collaborative processes) are essential for delivering complex, risky, multiple-stakeholders projects. Kermanshachi et al. [66] conducted an empirical study to identify the best practices and strategies to manage project complexity and increase the chance of success. Lu et al. [52] developed an evaluating model to assess complexity in large-scale projects considering the dynamic and emerging effects.

4.4. Risk Assessment and Uncertainty

Uncertainty and risk management practices positively correlate with perceived success in projects with high complexity [67]. Uncertainty refers to any deviation from anticipated project performance, and project complexity is an essential factor driving the uncertainty. Thus, in construction projects, understanding the three concepts of complexity–uncertainty−performance and modelling the nonlinear relationships between those constructs is necessary for developing an effective strategy to control risk and complexity [68].

For cluster #34, the most cited document was published by Adedokun et al. [47] assessing the adoption of qualitative risk analysis techniques (QRAT) in big construction projects. The study reveals that (QRAT) is not used sufficiently in evaluating the inherent risk in construction projects which is the reason for recorded time and cost overruns. Qualitative risk analysis is an important determinant factor for stakeholders to estimate the degree of project complexity. Identifying and addressing complexity in large construction projects help stakeholders to improve the planning process and achieve successful project delivery. Afzal et al. [69] reviewed the literature for all artificial intelligence (AI) methods used to evaluate cost-risk in construction projects to grasp complexity and uncertainty. Survey reveals that fuzzy hybrid methods are the most commonly used because those methods can measure complexity and underlying uncertainty. Erol et al. [70] examined the nature of the relationship between complexity and risk in mega construction projects. A conceptual framework was developed utilizing a qualitative approach, and the connections were verified using the qualitative approach. Thus, an integrated risk assessment process (IRAP) was formulated, which helps develop plans for risk management in mega-construction projects. Fang C and Marle F, [71] introduced a matrix-based risk propagation model to evaluate risk propagation considering the complexity of engineering projects. The model measures and ranks risks according to their impact on the project risk network.

5. Discussion

Bibliometric data can provide the necessary information to evaluate a particular field's performance in literature, assist research institutions in managing policies regarding fund allocation, and evaluate scientific inputs and outputs [72]. Moreover, findings obtained from the bibliometric analysis can also uncover the main factors that increase contribution in a specific field of study and direct researchers to carry out more studies effectively [73]. This review studies a refined search query to find 644 documents from the Scopus database related to project complexity in the construction industry. Statistics display that 47.7% of the collected documents are related to engineering and 22.9% related to business and management. Publications in this area exhibit an upward trend between 2006–2017, and the highest number of publications were in 2017 and 2019. The first research question of this study was regarding the identification of the most popular keywords in the field of construction project complexity, which can be seen in the keyword co-occurrence network generated using the VOSviewer tool. The top keywords were identified from the Scopus documents ranked by high-occurrence frequency and shown in Table 1. The second research question was to identify the most important authors and journals. Therefore, citation metrics were used and found the following authors: Anonymous, Baccarini, Williams, Flyvbjerg, Bosch-Rekveldt are among the top 10 authors in the field of project complexity. Additionally, the most cited journals are the Journal of Construction Engineering and Management, Engineering

Construction and Architectural Management, Journal of Management in Engineering, and International Journal of Project Management.

Regarding the third research question, which addressed the most prevalent themes of construction project complexity, the main research topics in the literature for construction project complexity were identified using document co-citation and clustering analysis. Literature of project complexity was classified into four main groups: identifying and measuring project complexity, schedule performance and cost estimation, systems integration and dynamic capabilities, and risk assessment and uncertainty. Finally, this study addressed the fourth research question regarding the current trends in project complexity literature and future research directions. According to Moed et al. [74] bibliometric analysis can evaluate research productivity and publications in a specific literature topic and explore research trends. From this study, research movements tend towards safety performance, organizational resilience, and integrated project delivery (IPD).

6. Conclusions and Future Research Directions

Construction project complexity has been snowballing over the past few years, and it has received more attention from scholars and practitioners. In this review, a scientometric methodology is suggested to conduct a thematic literature review for CPC and navigate the future research directions. Although a review work has been previously published for the CPC literature, this study is the first comprehensive review adopting the scientometric approach and including 644 academic documents examined to map the CPC literature. The frequent keywords, productive authors, top journal sources, and current research topics in the CPC literature were identified; simultaneously, future trends for construction project complexity were proposed. The prominent research topics in the literature on CPC are identifying and measuring project complexity, schedule performance and cost estimation, systems integration and dynamic capabilities, and risk assessment and uncertainty. Suggested future research directions include safety performance, organizational resilience, and integrated project delivery (IPD). The findings of this review have theoretical and practical implications for scholars and practitioners as the following:

- From the academic perspective, analyzing and laying out the literature of CPC will provide the scholars with systematic knowledge and a broad understanding of the research area;
- From a practical standpoint, practitioners in the field of construction should consider the findings of this review and perceive the impact of project complexity, which will assist in improving organizational performance.

Although this study contributes to the body of knowledge, the study still has a limitation. The review focuses only on the academic documents retrieved from the Scopus database, thus restricting the coverage of the reviewed literature relating to construction project complexity. It would be exciting to conduct a similar study with a broader range of CPC literature from other databases such as Web of Science, Google Scholar, and PubMed for future research. That would complement this review and monitor the research development in construction project complexity.

6.1. Future Research Directions

While the previous section discussed the current significant themes in the knowledge area of construction project complexity, the following section summarizes the potential future research trends on construction project complexity. The current trend in the literature on construction project complexity can be judged by manually reviewing and analyzing the current hotspots in recent publications. Thus, future research trends on construction project complexity include the following:

6.1.1. Safety Performance

In the construction industry, safety risks are growing due to the increasing degree of projects complexity. Resilient safety culture is suggested to handle these safety risks and achieve the intended safety performance. Interactive influences of resilient safety culture with project complexity on safety performance in construction projects were investigated, and the study shows that safety performance is negatively affected by technical and environmental complexities. Furthermore, a higher level of resilient safety culture moderates the negative impact of project complexity on safety performance; however, this moderating effect diminishes when increasing the resilient safety culture level [75]. Safety is an emergent phenomenon in a complex system with construction sites. Current safety management facing difficulties dealing with complexity and including situational self-organizing on construction sites is critical to improving the safety management system (SMS) [76]. Introducing Building Information Modeling (BMI) and industry revolution 4.0 technology into a dynamic model for the building industry would increase complexity and safety issues. However, establishing BIM in buildings reduces costs and improves management efficiency [77]. Complexity and resilience are interconnected features of construction projects. These features need to be observed with their impacts on safety management. The outcome of the Safety Performance Measurement System (SPMS) can be used to identify and monitor sources of complexity and resilience in construction projects [78].

6.1.2. Organizational Resilience

Project resilience is still an emergent knowledge area, and the resilience concept still needs more definition despite increasing research on this topic [79]. Geambasu [80]; conducted an empirical study on big infrastructure projects and was the first who introduce the concept of project resilience. The author has defined project resilience as "the project system's ability to restore capacity and continuously adapt to changes to fulfil its objectives to continue to function at its fullest possible extent, despite threatening critical events". The concept of project resilience has been processed by exchanging to advance research areas, and organizational resilience is the most established conceptual development of project resilience [81]. Construction projects are time-limit, focused contract, and dynamic (likely to influence disruptions). Construction projects can be defined as temporary multidisciplinary organizations (TMO), and organizational resilience in the (TMO) is the ability to be ready, respond and decrease the effects of disruptions resulting from project complexity [82]. Organizational resilience is a vital emergent attribute of an organization that refers to the hypothetic resilience characteristic. Organizational resilience cannot be described by joining any particular agent features, even in concept. Organizations composed of complex systems present a high degree of complexity as an emerging attribute covering the whole aspects of the organization. Resilience is also considered an emerging feature associated with such an organization of complex systems [83].

6.1.3. Integrated Project Delivery (IPD)

Integrated project delivery (IPD) is an emergent approach in the construction industry to minimize conflicts between project shareholders. Integrated project delivery (IPD) is a promising strategy used in traditional contracting systems to overcome inefficiency issues and promote project success [84]. However, due to increasing project complexity and rigorous legal rules, conventional practices became ineffective and led to conflicts, schedule delays, and cost overruns. Recently, integrated project delivery (IPD) system, including risk-sharing, trust, and collaboration, has been adopted as an efficient delivery practice [85]. Applying integrated project delivery (IDP) principles and practices in complex projects are widely expected. Additionally, utilizing IDP principles on small scales and fewer complex projects can be effective and enhance project team experience to be collaborative and more efficient [86]. Integrated project delivery (IPD) has been developed to tackle issues of the growing complexity of construction projects. Contracting culture should be supported to allow the broader adoption of IPD standards and practices for project performance [87].

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References

1. Morris, P.W.G. *The Management of Projects*; Thomas Telford: London, UK, 1994. [CrossRef]
2. Morris, P.W.G. Science, objective knowledge and the theory of project management. *Proc. Inst. Civ. Eng. Civ. Eng.* **2002**, *150*, 82–90. [CrossRef]
3. Bennett, J.; Fine, B. *Measurement of Complexity in Construction Projects*; Department of Construction Management, University of Reading: Reading, UK, 1980.
4. Bubshait, K.A.; Selen, W.J. Project characteristics that influence the implementation of project management techniques: A survey. *Int. J. Proj. Manag. J.* **1992**, *23*, 43–47.
5. Bennett, P.; Cropper, S. Uncertainty and conflict: Combining conflict analysis and strategic choice. *J. Behav. Decis. Mak.* **1990**, *3*, 29–45. [CrossRef]
6. Gidado, K. *Numerical Index of Complexity in Building Construction to its Effect on Production Time*; University of Brighton: Brighton, UK, 1993.
7. Wonziak, T.M. Significance VS Capability: "Fit for Use" Project Controls. *Am. Assoc. Cost Eng. Int. Trans.* **1993**, *2*, 1–8.
8. Baccarini, D. The concept of project complexity—A review. *Int. J. Proj. Manag.* **1996**, *14*, 201–204. [CrossRef]
9. Zolin, R.; Turner, R.; Remington, K. A Model of project complexity: Distinguishing dimensions of complexity from severity. In Proceedings of the International Research Network of Project Management Conference (IRNOP) IRNOP, Berlin, Germany, 11–13 October 2009.
10. Parsons-Hann, H.; Liu, K. Measuring requirements complexity to increase the probability of project success. In Proceedings of the Proceedings of the Seventh International Conference on Enterprise Information Systems, Miami, FL, USA, 25–28 May 2005; Volume 4, pp. 434–438.
11. Vidal, L.; Marle, F. Understanding project complexity: Implications on project management. *Kybernetes* **2008**, *37*, 1094–1110. [CrossRef]
12. Hess, D.J. *Science Studies: An Advanced Introduction*; NYU Press: New York, NY, USA, 1997.
13. Leydesdorff, L.; Milojević, S. Scientometrics. In *International Encyclopedia of the Social & Behavioral Sciences*; Elsevier BV: Amsterdam, The Netherlands, 2015; pp. 322–327.
14. Jin, R.; Zou, Y.; Gidado, K.; Ashton, P.; Painting, N. Scientometric analysis of BIM-based research in construction engineering and management. *Eng. Constr. Arch. Manag.* **2019**, *26*, 1750–1776. [CrossRef]
15. Van Eck, N.J.; Waltman, L. CitNetExplorer: A new software tool for analyzing and visualizing citation networks. *J. Inf.* **2014**, *8*, 802–823. [CrossRef]
16. Bankar, R.S.; Lihitkar, S.R. Science Mapping and Visualization Tools Used for Bibliometric and Scientometric Studies: A Comparative Study. *J. Adv. Libr. Sci.* **2019**, *6*, 382–394. [CrossRef]
17. Baarimah, A.O.; Alaloul, W.S.; Liew, M.S.; Kartika, W.; Al-Sharafi, M.A.; Musarat, M.A.; Alawag, A.M.; Qureshi, A.H. A Bibliometric Analysis and Review of Building Information Modelling for Post-Disaster Reconstruction. *Sustainability* **2021**, *14*, 393. [CrossRef]
18. Bakkalbasi, N.; Bauer, K.; Glover, J.; Wang, L. Three options for citation tracking: Google Scholar, Scopus and Web of Science. *Biomed. Digit. Libr.* **2006**, *3*, 7. [CrossRef] [PubMed]
19. Mongeon, P.; Paul-Hus, A. The journal coverage of Web of Science and Scopus: A comparative analysis. *Scientometrics* **2016**, *106*, 213–228. [CrossRef]
20. Al-Sharafi, M.A.; Al-Qaysi, N.; Iahad, N.A.; Al-Emran, M. Evaluating the sustainable use of mobile payment contactless technologies within and beyond the COVID-19 pandemic using a hybrid SEM-ANN approach. *Int. J. Bank Mark.* **2021**. [CrossRef]

21. Chadegani, A.A.; Salehi, H.; Yunus, M.M.; Farhadi, H.; Fooladi, M.; Farhadi, M.; Ebrahim, N.A. A Comparison between Two Main Academic Literature Collections: Web of Science and Scopus Databases. *Asian Soc. Sci.* **2013**, *9*, p18. [CrossRef]
22. Arpaci, I.; Al-Emran, M.; Al-Sharafi, M.A. The impact of knowledge management practices on the acceptance of Massive Open Online Courses (MOOCs) by engineering students: A cross-cultural comparison. *Telemat. Inform.* **2020**, *54*, 101468. [CrossRef]
23. Martín-Martín, A.; Orduna-Malea, E.; Thelwall, M.; Delgado López-Cózar, E. Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. *J. Informetr.* **2018**, *12*, 1160–1177. [CrossRef]
24. Mok, K.Y.; Shen, Q.; Yang, R. Stakeholder management studies in mega construction projects: A review and future directions. *Int. J. Proj. Manag.* **2015**, *33*, 446–457. [CrossRef]
25. Yalcinkaya, M.; Singh, V. Patterns and trends in Building Information Modeling (BIM) research: A Latent Semantic Analysis. *Autom. Constr.* **2015**, *59*, 68–80. [CrossRef]
26. Pollack, J.; Adler, D. Emergent trends and passing fads in project management research: A scientometric analysis of changes in the field. *Int. J. Proj. Manag.* **2015**, *33*, 236–248. [CrossRef]
27. Börner, K.; Chen, C.; Boyack, K.W. Visualizing knowledge domains. *Annu. Rev. Inf. Sci. Technol.* **2005**, *37*, 179–255. [CrossRef]
28. Liu, J.-W.; Huang, L.-C. Detecting and Visualizing Emerging Trends and Transient Patterns in Fuel Cell Scientific Literature. In Proceedings of the 2008 4th International Conference on Wireless Communications, Networking and Mobile Computing, Dalian, China, 12–14 October 2008; pp. 1–4.
29. Su, H.-N.; Lee, P.-C. Mapping knowledge structure by keyword co-occurrence: A first look at journal papers in Technology Foresight. *Scientometrics* **2010**, *85*, 65–79. [CrossRef]
30. Song, J.; Zhang, H.; Dong, W. A review of emerging trends in global PPP research: Analysis and visualization. *Scientometrics* **2016**, *107*, 1111–1147. [CrossRef]
31. Cobo, M.J.; López-Herrera, A.G.; Herrera-Viedma, E.; Herrera, F. Science mapping software tools: Review, analysis, and cooperative study among tools. *J. Am. Soc. Inf. Sci. Technol.* **2011**, *62*, 1382–1402. [CrossRef]
32. Van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [CrossRef] [PubMed]
33. Perianes-Rodriguez, A.; Waltman, L.; van Eck, N.J. Constructing bibliometric networks: A comparison between full and fractional counting. *J. Inf.* **2016**, *10*, 1178–1195. [CrossRef]
34. Oraee, M.; Hosseini, M.R.; Papadonikolaki, E.; Palliyaguru, R.; Arashpour, M. Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review. *Int. J. Proj. Manag.* **2017**, *35*, 1288–1301. [CrossRef]
35. Boyack, K.; van Eck, N.J.; Colavizza, G.; Waltman, L. Characterizing in-text citations in scientific articles: A large-scale analysis. *J. Inf.* **2018**, *12*, 59–73. [CrossRef]
36. Wu, Y.; Wang, H.; Wang, Z.; Zhang, B.; Meyer, B.C. Knowledge Mapping Analysis of Rural Landscape Using CiteSpace. *Sustainability* **2020**, *12*, 66. [CrossRef]
37. Chen, C.; Morris, S. Visualizing evolving networks: Minimum spanning trees versus pathfinder networks. In Proceedings of the IEEE Symposium on Information Visualization 2003, (IEEE Cat. No.03TH8714), Seattle, WA, USA, 19–23 October 2003; IEEE: Piscataway, NJ, USA, 2004; pp. 67–74.
38. Newman, M.E.J. Modularity and community structure in networks. *Proc. Natl. Acad. Sci. USA* **2006**, *103*, 8577–8582. [CrossRef]
39. Kaufman, L.; Rousseeuw, P.J. *Finding Groups in Data: An Introduction to Cluster Analysis*; John Wiley & Sons: Hoboken, NJ, USA, 2009.
40. Chen, C. *CiteSpace: A Practical Guide for Mapping Scientific Literature*; Nova Science Publishers: Hauppauge, NY, USA, 2016.
41. Lu, Y.; Luo, L.; Wang, H.; Le, Y.; Shi, Q. Measurement model of project complexity for large-scale projects from task and organization perspective. *Int. J. Proj. Manag.* **2015**, *33*, 610–622. [CrossRef]
42. Nguyen, L.D.; Le-Hoai, L.; Tran, D.Q.; Dang, C.; Nguyen, C.V. Effect of project complexity on cost and schedule performance in transportation projects. *Constr. Manag. Econ.* **2019**, *37*, 384–399. [CrossRef]
43. Akintoye, A. Analysis of factors influencing project cost estimating practice. *Constr. Manag. Econ.* **2000**, *18*, 77–89. [CrossRef]
44. Davies, A.; Mackenzie, I. Project complexity and systems integration: Constructing the London 2012 Olympics and Paralympics Games. *Int. J. Proj. Manag.* **2014**, *32*, 773–790. [CrossRef]
45. Xia, B.; Chan, A.P. Measuring complexity for building projects: A Delphi study. *Eng. Constr. Arch. Manag.* **2012**, *19*, 7–24. [CrossRef]
46. Chen, Y.; Wang, W.; Zhang, S.; You, J. Understanding the multiple functions of construction contracts: The anatomy of FIDIC model contracts. *Constr. Manag. Econ.* **2018**, *36*, 472–485. [CrossRef]
47. Adedokun, O.; Ogunsemi, D.; Aje, I.; Awodele, O.; Dairo, D. Evaluation of qualitative risk analysis techniques in selected large construction companies in Nigeria. *J. Facil. Manag.* **2013**, *11*, 123–135. [CrossRef]
48. Luo, L.; He, Q.; Jaselskis, E.J.; Xie, J. Construction Project Complexity: Research Trends and Implications. *J. Constr. Eng. Manag.* **2017**, *143*, 04017019. [CrossRef]
49. Luo, L.; He, Q.; Xie, J.; Yang, D.; Wu, G. Investigating the Relationship between Project Complexity and Success in Complex Construction Projects. *J. Manag. Eng.* **2017**, *33*, 04016036. [CrossRef]
50. Eriksson, P.E.; Larsson, J.; Pesämaa, O. Managing complex projects in the infrastructure sector—A structural equation model for flexibility-focused project management. *Int. J. Proj. Manag.* **2017**, *35*, 1512–1523. [CrossRef]

51. Ahn, S.; Shokri, S.; Lee, S.; Haas, C.T.; Haas, R.C.G. Exploratory Study on the Effectiveness of Interface-Management Practices in Dealing with Project Complexity in Large-Scale Engineering and Construction Projects. *J. Manag. Eng.* **2017**, *33*, 04016039. [CrossRef]
52. Sohi, A.J.; Bosch-Rekveldt, M.; Hertogh, M. Four stages of making project management flexible: Insight, importance, implementation and improvement. *Organ. Technol. Manag. Constr. Int. J.* **2020**, *12*, 2117–2136. [CrossRef]
53. Nguyen, A.T.; Nguyen, L.D.; Le-Hoai, L.; Dang, C. Quantifying the complexity of transportation projects using the fuzzy analytic hierarchy process. *Int. J. Proj. Manag.* **2015**, *33*, 1364–1376. [CrossRef]
54. Luo, L.; Zhang, L.; Wu, G. Bayesian belief network-based project complexity measurement considering causal relationships. *J. Civ. Eng. Manag.* **2020**, *26*, 200–215. [CrossRef]
55. Nguyen, L.D.; Tran, D.Q.; Nguyen, A.T.; Le-Hoai, L. Computational model for measuring project complexity in construction. In Proceedings of the 2016 Annual Conference of the North American Fuzzy Information Processing Society (NAFIPS), El Paso, TX, USA, 31 October–4 November 2016; IEEE: Piscataway, NJ, USA, 2017; pp. 1–5.
56. Cooke, T. Can knowledge sharing mitigate the effect of construction project complexity? *Constr. Innov.* **2013**, *13*, 5–9. [CrossRef]
57. Wood, H.; Gidado, K. *Project Complexity in Construction*; RICS Foundation: London, UK, 2008.
58. Bosch-Rekveldt, M. *Managing Project Complexity: A Study into Adapting Early Project Phases to Improve Project Performance in Large Engineering Projects*; Delft University of Technology: Delft, The Netherlands, 2011.
59. Hietajärvi, A.-M.; Aaltonen, K.; Haapasalo, H. Managing integration in infrastructure alliance projects. *Int. J. Manag. Proj. Bus.* **2017**, *10*, 5–31. [CrossRef]
60. Hartono, B.; Wijaya, D.F.; Arini, H.M. The impact of project risk management maturity on performance: Complexity as a moderating variable. *Int. J. Eng. Bus. Manag.* **2019**, *11*. [CrossRef]
61. Damayanti, R.W.; Hartono, B.; Wijaya, A.R. Project Managers' Perspectives on the Complexity of Construction Megaproject in Indonesia: A Multicase Study. *IEEE Eng. Manag. Rev.* **2021**, *49*, 153–171. [CrossRef]
62. Hietajärvi, A.-M.; Aaltonen, K.; Haapasalo, H. What is project alliance capability? *Int. J. Manag. Proj. Bus.* **2017**, *10*, 404–422. [CrossRef]
63. Siemieniuch, C.; Sinclair, M. Systems integration. *Appl. Ergon.* **2006**, *37*, 91–110. [CrossRef]
64. Brady, T.; Davies, A. Managing Structural and Dynamic Complexity: A Tale of Two Projects. *Proj. Manag. J.* **2014**, *45*, 21–38. [CrossRef]
65. Davies, A.; Dodgson, M.; Gann, D. Dynamic Capabilities in Complex Projects: The Case of London Heathrow Terminal 5. *Proj. Manag. J.* **2016**, *47*, 26–46. [CrossRef]
66. Kermanshachi, S.; Dao, B.; Shane, J.; Anderson, S. An Empirical Study into Identifying Project Complexity Management Strategies. *Procedia Eng.* **2016**, *145*, 603–610. [CrossRef]
67. Harvett, C.M. A Study of Uncertainty and Risk Management Practice Relative to Perceived Project Complexity. Ph.D. Thesis, Bond University, Robina, Australia, 2013.
68. Dikmen, I.; Qazi, A.; Erol, H.; Birgonul, M.T. Meta-Modeling of Complexity-Uncertainty-Performance Triad in Construction Projects. *Eng. Manag. J.* **2021**, *33*, 30–44. [CrossRef]
69. Afzal, F.; Yunfei, S.; Nazir, M.; Bhatti, S.M. A review of artificial intelligence based risk assessment methods for capturing complexity-risk interdependencies. *Int. J. Manag. Proj. Bus.* **2019**, *14*, 300–328. [CrossRef]
70. Erol, H.; Dikmen, I.; Atasoy, G.; Birgonul, M.T. Exploring the Relationship between Complexity and Risk in Megaconstruction Projects. *J. Constr. Eng. Manag.* **2020**, *146*, 04020138. [CrossRef]
71. Fang, C.; Marle, F. Dealing with project complexity by matrix-based propagation modelling for project risk analysis. *J. Eng. Des.* **2013**, *24*, 239–256. [CrossRef]
72. Gu, Y. Global knowledge management research: A bibliometric analysis. *Sci.* **2004**, *61*, 171–190. [CrossRef]
73. Akhavan, P.; Ebrahim, N.A.; Fetrati, M.A.; Pezeshkan, A. Major trends in knowledge management research: A bibliometric study. *Scientometrics* **2016**, *107*, 1249–1264. [CrossRef]
74. Moed, H.F.; Luwel, M.; Nederhof, A.J.; Mocd, H.F.; Luwel, M. Towards Research Performance in the Humanities. *Library Trends* **2002**, *50*, 498–520.
75. Trinh, M.T.; Feng, Y. Impact of Project Complexity on Construction Safety Performance: Moderating Role of Resilient Safety Culture. *J. Constr. Eng. Manag.* **2020**, *146*, 04019103. [CrossRef]
76. Sherratt, F.; Ivory, C. Managing "a little bit unsafe": Complexity, construction safety and situational self-organising. *Eng. Constr. Arch. Manag.* **2019**, *26*, 2519–2534. [CrossRef]
77. Hotový, M. Dynamic model of implementation efficiency of Building Information Modelling (BIM) in relation to the complexity of buildings and the level of their safety. *MATEC Web Conf.* **2018**, *146*, 1010. [CrossRef]
78. Peñaloza, G.A.; Saurin, T.A.; Formoso, C.T. Monitoring complexity and resilience in construction projects: The contribution of safety performance measurement systems. *Appl. Ergon.* **2020**, *82*, 102978. [CrossRef]
79. Thomé, A.M.T.; Scavarda, L.F.; Scavarda, A.; Thomé, F.E.S.D.S. Similarities and contrasts of complexity, uncertainty, risks, and resilience in supply chains and temporary multi-organization projects. *Int. J. Proj. Manag.* **2016**, *34*, 1328–1346. [CrossRef]
80. Geambasu, G. Expect the Unexpected:An Exploratory Study on the Conditions and Factors Driving the Resilience of Infrastructure Projects. Ph.D. Thesis, École Polytechnique Fédérale de Lausanne, Laussane, Switzerland, 2011.
81. Rahi, K. Project resilience: A conceptual framework. *Int. J. Inf. Syst. Proj. Manag.* **2019**, *7*, 69–83. [CrossRef]

82. Blay, K. The Impact of Inclusiveness on Resilience in Temporary Multidisciplinary Organizations (TMO). In *Construction Research Congress 2018*; American Society of Civil Engineers: Reston, VA, USA, 2018; pp. 243–252.
83. Pariès, J. Complexity, Emergence, Resilience &hellip. In *Resilience Engineering*; CRC Press: Boca Raton, FL, USA, 2017; pp. 43–53.
84. De Marco, A.; Karzouna, A. Assessing the Benefits of the Integrated Project Delivery Method: A Survey of Expert Opinions. *Procedia Comput. Sci.* **2018**, *138*, 823–828. [CrossRef]
85. Pal, A.; Nassarudin, A. Integrated Project Delivery Adoption Framework for Construction Projects in India. In Proceedings of the 28th Annual Conference of the International Group for Lean Construction (IGLC), Berkeley, CA, USA, 6–10 July 2020; Volume 28, pp. 337–348. [CrossRef]
86. Jenkins, G.; Smith, J.P.; Bingham, E.; Weidman, J. Application of Integrated Project Delivery Practices in Residential Construction. In Proceedings of the 28th Annual Conference of the International Group for Lean Construction (IGLC), Berkeley, CA, USA, 6–10 July 2020; Volume 28, pp. 769–781. [CrossRef]
87. Ahmed, M.O.; Nabi, M.A.; El-Adaway, I.H.; Caranci, D.; Eberle, J.; Hawkins, Z.; Sparrow, R. Contractual Guidelines for Promoting Integrated Project Delivery. *J. Constr. Eng. Manag.* **2021**, *147*, 05021008. [CrossRef]