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Review

Supply Chain Management for the Engineering Procurement and Construction (EPC) Model: A Review and Bibliometric Analysis

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Abstract: China's "Going Out" strategy and the "Belt and Road" initiative have significantly propelled the expansion of overseas contractual engagements, with a pronounced impact in the Engineering, Procurement, and Construction (EPC) sector. EPC contracting is increasingly recognized for its superior resource allocation and integration efficiency. Within the EPC framework, procurement is pivotal, exerting a direct influence on project cost, schedule, and quality parameters. The biblio-metric analysis of this paper reveals the research trend of EPC projects in the past decade, especially in supply chain integration, procurement management, and stakeholder management. This indicates an increasing interest in efficient project management and supply chain optimization in international engineering EPC projects. Although the application of supply chain integration in the manufacturing industry has been a successful experience, its practical application in construction and EPC projects is still insufficient. Integration strategies mentioned in the literature, such as achieving supply chain transparency through digital platforms, reducing operating costs, and optimizing delivery time, are directions that need to be further explored in this field. Effective supply chain integration and increased maturity of procurement management in EPC projects are still less involved areas. In addition, there is also a lack of research on how to manage high-risk and unpredictable risks in large international engineering projects. This article suggests that future research should focus on developing flexible supply chain management tools and practices to adapt to a project-oriented supply chain environment.

Keywords: international project; supply chain; EPC project; stakeholder management

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1. Introduction

Effective supply chain management (SCM) has become a cornerstone of successful project execution, impacting cost efficiency, timely delivery, and quality control. In complex, large-scale projects, SCM facilitates coordination among various stakeholders and enhances the flow of information and resources. Industries such as manufacturing have demonstrated the significant benefits of integrating SCM to streamline operations, reduce costs, and improve performance. Despite the demonstrated success of SCM integration in manufacturing, its practical application within the construction industry—especially in international EPC projects—has been limited.

The growth of China's overseas contract engineering business is fundamentally driven by the strategic initiatives of "Globalization" and the "Belt and Road" initiative, significantly shaping the Engineering, Procurement, and Construction (EPC) sector. The EPC model, which integrates design, procurement, and construction into a single contractual framework, has become the preferred approach for project execution because of its efficacy in resource allocation and integration across the project lifecycle. Research by Luo et al. [1] underscores the importance of work breakdown structures (WBSs) and modular breakdown structures (MBSs) in enhancing control over supply chain processes in EPC projects.

Procurement, a critical component of the EPC model, has a direct impact on financial and operational metrics, including cost, schedule, and quality. Wang et al. [2] identified 25 key procurement risk factors in international EPC projects, highlighting the necessity of a comprehensive analysis of the natural, economic, legal, and political contexts of the host country.

The EPC model is distinguished by its single point of responsibility throughout the entire project lifecycle, which facilitates streamlined communication and enhances overall efficiency. This characteristic enables contractors to assume the risks associated with project delivery, setting it apart from other contracting models such as Design–Build (DB) and Turnkey contracts, each of which has unique applications depending on specific project requirements and industry contexts.

Figure 1 illustrates the structural intricacies of the EPC model, detailing its phases, key stakeholders, and processes. This diagram serves as a foundational reference for understanding the operational dynamics inherent in EPC contracting.

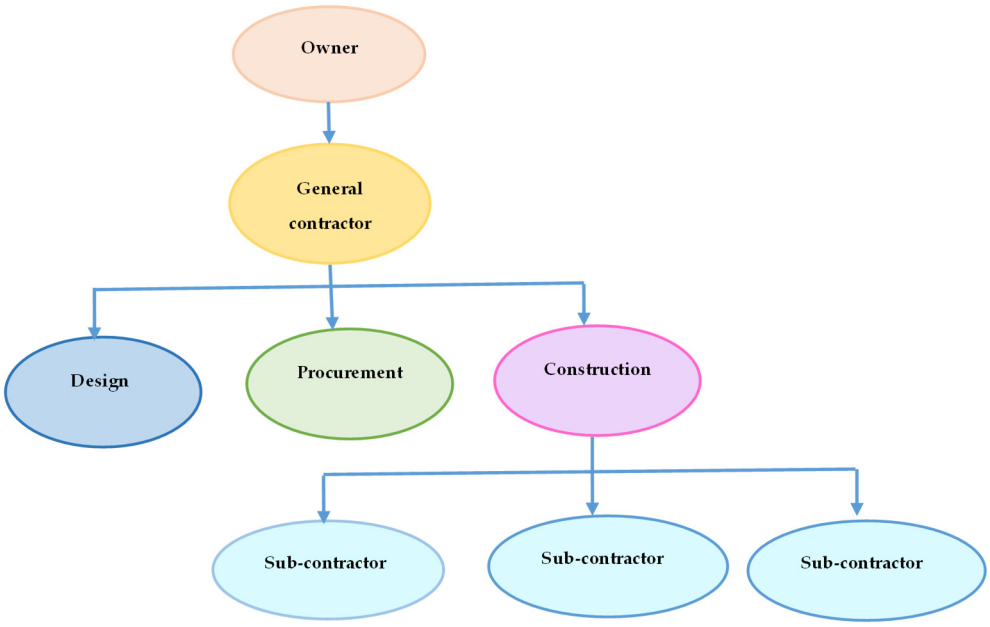

Figure 1. Structural diagram of the EPC general contracting mode.

This paper posits that the integration of supply chain management (SCM) into procurement processes is essential for enhancing efficiency and reducing costs in international EPC projects. Effective SCM can improve coordination and procurement management through strategic partnerships with suppliers and stakeholders, thereby elevating project performance. Luo et al. [3] proposed an innovative cooperation model that incorporates carbon emission rights into EPC energy projects, opening new financing avenues that address traditional challenges in EPC financing.

However, procurement within international EPC projects presents complex challenges. Traditional procurement management often fosters temporary, contractual relationships among contractors, suppliers, owners, and consultants. This perspective can lead to inefficiencies, such as poor interface management and a lack of collaboration, negatively impacting project quality. This paper advocates for adopting supply chain integration strategies that prioritize long-term, cooperative relationships, facilitating seamless information and resource flows, thus enhancing supply chain efficiency.

Despite the successful integration of supply chains in manufacturing, its application within the construction sector—particularly in EPC contexts—remains limited. This study aims to bridge this gap by emphasizing the critical need for implementing SCM in EPC procurement management. Contractors are encouraged to view procurement as a mechanism for supply chain value creation, maximizing stakeholder contributions.

The supply chain in the construction industry is inherently project-centric and temporary, presenting challenges for the application of traditional SCM tools. These tools, designed for stable supply chains in manufacturing, may not effectively transfer to the construction sector, necessitating a more adaptable SCM approach to manage the fluidity of project-based supply chains [4–6].

While numerous scholars have explored international engineering management to enhance procurement in global projects, the implementation of SCM integration within construction project management is still in its infancy [7–9]. This paper conducts a comprehensive literature review and bibliometric analysis of SCM in international EPC projects, addressing key questions regarding the current state of research, critical factors in procurement management, and the role of procurement in these projects [7–9].

To enhance procurement operations in multinational EPC projects, contractors must integrate management systems with a focus on supply chain value creation. Achieving commendable procurement performance is vital for gaining a competitive edge in the market. A thorough review of the academic research in this area is essential to better understand these dynamics.

The structure of this study is organized as follows: Section 2 provides a detailed overview of the research methodology and the data utilized. Section 3 presents the results of this study, including an analysis of selected research papers and survey findings, with a focus on procurement management, supply chain integration, and stakeholder management in international EPC projects. Section 4 engages in a comprehensive discussion of the implications of these findings, contextualizing them within the existing literature and exploring their relevance to the field. Finally, Section 5 concludes this study, summarizing the key findings and proposing directions for future research.

In conclusion, the future of EPC projects is closely linked to the adoption of sustainable practices. As this study's literature review and analysis have shown, there is a clear trend toward integrating SCM into EPC procurement processes to enhance efficiency, reduce costs, and improve project performance while also addressing environmental and social impacts. EPC contractors must commit to sustainable development, ensuring their projects yield positive outcomes for the environment and communities they serve. This commitment is essential for achieving outstanding procurement performance and maintaining a competitive edge, aligning with broader sustainability goals within the construction industry.

2. Materials and Methods

2.1. Development of a Corpus of International Engineering EPC Projects

To facilitate our analysis, we employed a systematic literature review methodology to assemble a database of relevant articles. Our aim was to capture the most recent and pertinent research developments; hence, we established a search timeframe spanning from 2005 to 2024. The initial phase of our literature search involved querying two prominent databases: the Web of Science Core Collection (WOS) and Scopus. Our search strategy targeted the "title", "abstract", and "keywords" fields of documents, utilizing a carefully selected array of keywords associated with "EPC project", "supply chain in construction", "stakeholder management", and "procurement management in construction".

To the array of publications retrieved from WOS and Scopus, we applied stringent criteria to refine our selection, excluding books and conference papers to focus exclusively on scholarly journal articles. This meticulous selection process was designed to ensure the inclusion of high-quality, peer-reviewed academic research in our analysis. The intricate search syntax that guided this process is detailed in Table 1 of our study.

Table 1. Syntax to compile research on EPC projects.

Data Source	Syntax
Web of Science Core Collection www.webofscience.com (accessed on 15 September 2024)	First layer: TS = ("International project*") NOT TS = (equipment OR "Electronic product code") Second layer: (1) TS = ("EPC project" OR general contract project); (2) TS = (Supply chain OR Supply chain management in the construction); (3) TS = (Stakeholder management); (4) TS = (Procurement management in the construction)
Scopus www.scopus.com (accessed on 15 September 2024)	First layer: TITLE-ABS-KEY (International project) Second layer: (1) TITLE-ABS-KEY ("EPC project" OR general contract project); (2) TITLE-ABS-KEY (Supply chain OR Supply chain management in the construction); (3) TITLE-ABS-KEY (Stakeholder management); (4) TITLE-ABS-KEY (Procurement management in the construction)

Continuing with our exposition, Table 2 provides a comprehensive summary of the literature search outcomes, encapsulating key metrics and insights from the body of work reviewed.

Table 2. Overview of literature search results.

Period		Type	Number of Research Articles
2005–2024	International project	EPC project	WOS + Scopus: 34 + 4→37 (Duplicate: 1)
2005–2024		Supply chain in construction	WOS + Scopus: 39 + 2→41 (Duplicate: 1)
2005–2024		Stakeholder management	WOS + Scopus: 921 + 4→924 (Duplicate:1)
2005–2024		Procurement management in construction	WOS + Scopus: 226 + 6→232 (Duplicate: 2)
			TOTAL: 1220 (Duplicate: 5)

To visually articulate the structured approach underpinning our literature review, Figure 2 presents a schematic outline of the entire review process. This diagrammatic representation serves as a navigational tool, illustrating the sequential steps and decision-making junctures that shaped the curation of our article database, which underpins the subsequent analysis and discussion presented in our research.

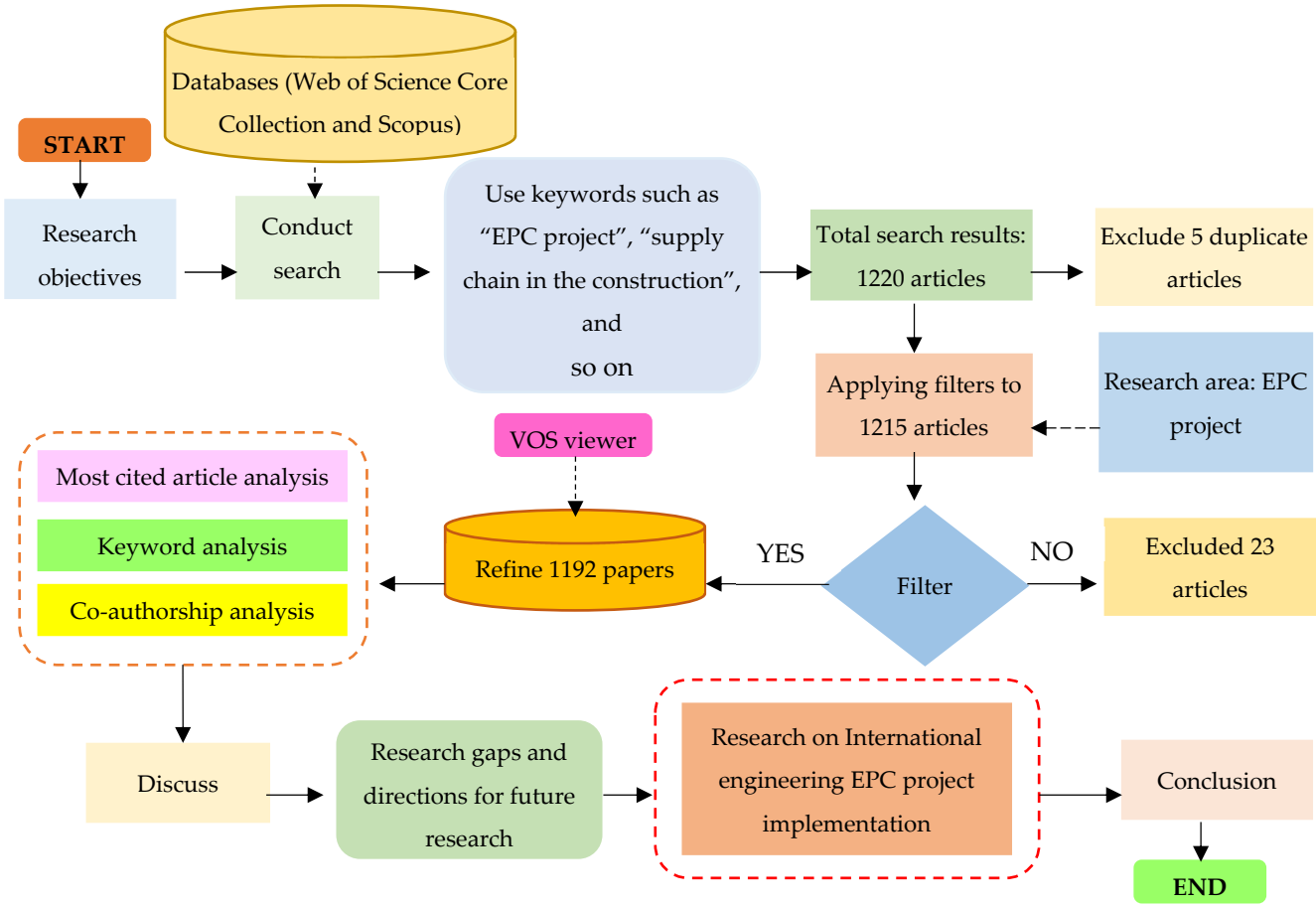

Figure 2. Flowchart illustrating the review procedure and database construction process.

2.2. Most Cited Papers

Utilizing the citation count metrics sourced from the Web of Science (WOS) and Scopus databases, we conducted a ranking of the scholarly articles pertaining to the management of international engineering EPC projects. This ranking was based on the number of citations each article received, which served as an indicator of the research's influence and relevance within the academic community. In addition to this bibliometric analysis, we synthesized a summary that encapsulates the research methodologies and principal discoveries of the papers that have garnered the most scholarly attention.

Because of the voluminous literature surrounding the management of international engineering EPC projects, our focus was narrowed to the top 10 most cited papers within each keyword category. These articles represent the forefront of academic thought and have significantly shaped our current understanding in the fields of procurement management, supply chain integration, and stakeholder management within the EPC project management discipline. The articles with the highest citation counts were selected to provide a snapshot of the most impactful studies, as detailed in Section 3.1 of our research.

This methodical curation of the literature not only underscores the pivotal contributions to the field but also offers a valuable perspective on the diversity of research approaches and the findings that have emerged from these investigations. By examining the most cited works, we gained a comprehensive view of the prevailing methodologies and the insights they have yielded, which are instrumental in advancing the discourse on international EPC project management.

2.3. Semantics

In our study, we performed a co-occurrence network analysis of keywords from a range of articles to map the research landscape of international EPC project management.

This method uncovered the main themes, connections between concepts, and the direction of scholarly pursuit in the field.

We analyze keyword co-occurrence frequencies and patterns to gain insight into the field's intellectual structure, highlighting active research clusters and identifying literature gaps for potential investigation.

We employed VOS viewer 1.6.20 to visualize and interpret keyword and author collaboration networks. VOS viewer generates graphs that depict the strength of keyword associations and maps author networks, aiding in understanding research trends and guiding scholars through the complex terrain of EPC project management research.

3. Results

3.1. Results of the Most Cited Articles

In our study, we categorized and analyzed influential articles on EPC projects, procurement management, supply chain integration, and stakeholder theory based on citation counts. The top 10 papers in each area amassed 622, 351, 1125, and 928 citations, respectively.

3.1.1. The Most Cited Articles Related to International Engineering EPC Projects

Our tables present research methods, geographic focus, and key findings. For instance, Table 3 synthesizes the management of EPC projects internationally, highlighting diverse global research including the U.S., China, the U.K., Africa, Pakistan, and Fiji. This diversity shows the global reach of EPC project management research.

The most cited papers in Table 3 investigate critical success factors for EPC projects. The studies by R Pal et al. [10] and N. D. Caldwell et al. [11] explore supplier services, external risks, and governance mechanisms, enhancing our understanding of EPC projects worldwide [10,11].

Table 3. The most cited articles related to international engineering EPC projects.

No.	Authors	Year	Title	Methods	Area	Results	Citations
1	R Pal; P Wang and X Liang [10]	2017	The critical factors in managing relationships in international engineering, procurement, and construction (IEPC) projects of Chinese organizations	Questionnaire survey	China	The key factors influencing IEPC project success are supplier service, continuous improvement, delivery reliability, and problem-solving.	113
2	Wenxin Shen [12]	2017	Causes of contractors' claims in international engineering-procurement-construction projects	A combination of qualitative and quantitative methods	Africa and Asia Pacific	The study used SEM to examine external risk, client behavior, project contract definitions, and claims in international EPC projects, analyzing their interrelations.	103
3	N. D. Caldwell, J. K. Roehrich and A. C. Davies [11]	2009	Procuring complex performance in construction: London Heathrow Terminal 5 and a Private Finance Initiative hospital	Case study case analysis	Britain	The study results highlight that the choice of governance mechanisms in upstream relationships critically relates to subsequent project performance outcomes	101

Table 3. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
4	Wang, TF; Tang, WZ; (...); Wei, YP [13]	2016	Relationships among Risk Management, Partnering, and Contractor Capability in International EPC Project Delivery	A combination of qualitative and quantitative methods	China	The study indicates that partnerships enhance risk management in international EPC projects by boosting contractor capabilities and directly improving risk handling.	50
5	Shen, WX; Tang, WZ; (...); You, RC [14]	2017	Enhancing Trust-Based Interface Management in International Engineering-Procurement-Construction Projects	Quantitative Analysis	China	The survey results indicate that trust levels are relatively high between contractors and owners, suppliers, and designers, while trust with local residents was lower.	47
6	Rudolf, CA and Spinler, S [15]	2018	Key risks in the supply chain of large scale engineering and construction projects	Questionnaire survey	Global	The results suggest that generic risk management is prevalent in large-scale projects, yet supply chain risk management (SCRM) is less common, with only 64% of surveyed participants employing SCRM and 72% recognizing the need to tailor processes for supply chain risk in large projects.	31
7	Wang, TF; Tang, WZ; (...); Huang, M [16]	2016	Enhancing Design Management by Partnering in Delivery of International EPC Projects: Evidence from Chinese Construction Companies	Quantitative Analysis	China	The study reveals that partnerships significantly influence design management and outcomes in international EPC hydropower projects. The critical role of partnerships is confirmed, with effective design management being essential to project performance, and partnerships contributing to enhanced design management and improved project results.	31

Table 3. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
8	Ishii, N; Takano, Y and Muraki, M [17]	2014	An order acceptance strategy under limited engineering man-hours for cost estimation in Engineering-Procurement-Construction projects	Quantitative Analysis	Global	The results suggest that balancing engineering man-hours for cost estimation and execution enhances long-term expected profit in EPC projects with competitive bidding.	22

3.1.2. The Most Cited Articles Related to Supply Chain Management in Construction

Table 4 presents the most cited articles related to supply chain integration in international engineering. The analysis reveals that quantitative methodologies are predominant in these studies, enabling researchers to generate statistical insights and identify patterns in supply chain performance. These quantitative studies often employ surveys and data analysis techniques to assess various factors influencing supply chain integration.

Table 4. The most cited articles related to supply chain management in construction.

No.	Authors	Year	Title	Methods	Area	Results	Citations
1	Pal, R; Wang, P and Liang, XP [10]	2017	The critical factors in managing relationships in international engineering, procurement, and construction (IEPC) projects of Chinese organizations	Quantitative research (logistic regression and neural network analysis methods were used in the analyses)	China	The study pinpoints four key factors affecting IEPC project success: supplier and subcontractor services, continuous improvement, delivery reliability, and effective problem-solving. These results offer guidance for IEPC project management, suggesting that main contractors prioritize these factors for better relationship management outcomes.	128
2	Kabirifar, K and Mojtahedi, M [18]	2019	The impact of Engineering, Procurement and Construction (EPC) Phases on Project Performance: A Case of Large-scale Residential Construction Project	Quantitative research, TOPSIS	Iran	The results indicate that engineering design, project planning, and control significantly influence project performance, with design being paramount, followed by construction. Interestingly, procurement is deemed more critical than construction. Consequently, future research should enhance key factors like engineering design, planning, control, and material quality, and compare and refine contractors' project management approaches.	45

Table 4. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
3	Liu, KN; Su, YK and Zhang, SJ [19]	2018	Evaluating Supplier Management Maturity in Prefabricated Construction Project-Survey Analysis in China	A combination of qualitative and quantitative research methods	China	The article proposed an evaluation system for assessing supplier management maturity (SMM) and designed a five-level maturity matrix. A questionnaire survey and semi-structured interviews were conducted with 34 large prefabricated construction companies in the Yangtze River Delta region of China. The research results show the following: The overall level of supplier management maturity is relatively low, and there are still problems in supply chain integration. Relationship coordination and strategic collaboration lag behind procurement management and operational efficiency. Single-business contractors, EPC contractors, and contractors with more construction experience have higher SMM levels. In terms of corporate social responsibility, there is no significant difference in the performance of various types of contractors.	34
4	Rudolf, CA and Spinler, S [15]	2018	Key risks in the supply chain of large scale engineering and construction projects	A combination of qualitative and quantitative research methods	Global	The study shows that the supply chain risk profile for large-scale projects is distinct, with behavioral risks being prominent. Initial risk assessments are typically biased and underestimated. A specialized risk classification system for large-scale projects was suggested, offering a structured approach to risk management. The research advocates for more quantitative analysis to address the shortcomings of expert opinion in managing volatile supply chain risks in major projects.	27

Table 4. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
5	Lars Bankvall, Lena E. Bygballe, A. Dubois, Marianne Jahre [20]	2010	Interdependence in supply chains and projects in construction	Case study	Unknown	The study identifies issues in construction industry supply chain management, stemming from the sector's complex interdependencies, which current theories and models, focused on sequential dependence, fail to address adequately. Construction projects demand frequent, direct interactions for reciprocal adjustments, beyond what better planning alone can achieve. A deeper comprehension of the various interdependencies and their management is crucial for advancing construction supply chain management understanding.	18
6	A. Segerstedt, T. Olofsson [21]	2010	Supply chains in the construction industry	The article mainly uses a literature review and official statistical data	Sweden	The construction industry's distinct nature from traditional manufacturing necessitates tailored solutions. Its volatility and cyclicality present substantial supply chain management challenges. Enhancing productivity requires addressing issues like design-production separation. Future research should test the hypothesis that planning, synchronization, and flexibility outweigh integration and explore the transition to mature lean construction implementation. Investigating strategic alliance success factors, such as central coordination, IT solutions, and trust, is also essential.	18
7	Lars-Erik Gadde, A. Dubois [22]	2010	Partnering in the construction industry—Problems and opportunities	Qualitative literature review analysis method	Global	Achieving desired outcomes in construction strategic partnerships is difficult because unique supply arrangements differ from "high-involvement relationships". Revising industry norms may be necessary to realize partnership benefits. A tiered approach at project, regional, and central levels is recommended, with research focusing on establishing partnerships, modifying industry foundations, and coordinating across levels.	15

Table 4. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
8	Panchanan Behera, R. P. Mohanty, A. Prakash [23]	2015	Understanding Construction Supply Chain Management	Qualitative literature review analysis method	Global	Construction supply chain management is evolving to address 21st-century challenges, requiring managers to carefully define their supply chains. The study introduces a conceptual model to enhance project progress and meet community expectations via integration, coordination, collaboration, and attention to health, safety, risk, and environmental processes. Future research should empirically test this model and consider varying needs across construction project processes since the proposed measures may not apply universally.	128
9	D. Aloini, Riccardo Dulmin, Valeria Mininno, S. Ponticelli [24]	2012	Supply chain management: a review of implementation risks in the construction industry	Qualitative literature review analysis method	Global	The article highlights 13 key risk factors impacting construction industry supply chain management, analyzing their attributes and decision-making levels. It notes a paucity of literature on construction supply chain risk management (CSCRM), predominantly concentrating on risk identification. Emphasis should shift to risk quantification and response/control in later stages of risk management. Future studies ought to encompass a broader range of construction supply chain participants beyond the general contractor.	45
10	M. Thunberg, A. Fredriksson [25]	2018	Bringing planning back into the picture—How can supply chain planning aid in dealing with supply chain-related problems in construction?	A qualitative research method, including semi-structured interviews and case studies	Sweden	The study presents a conceptual model elucidating the link between operational supply chain challenges and inadequate company or pre-planning. It proposes that supply chain planning can address prevalent issues like trust deficits, poor communication, and lack of standardization in construction. Future research should examine how various planning activities can tackle these problems and test the model's relevance across different scenarios.	34

In contrast, qualitative assessments and case studies complement this quantitative approach by providing a richer, more nuanced understanding of supply chain management in the construction industry. These qualitative studies delve into specific examples, exploring the intricacies of supply chain dynamics, stakeholder interactions, and the contextual fac-

tors that affect project outcomes. By integrating both quantitative and qualitative methods, researchers can gain a comprehensive view of supply chain integration, highlighting best practices and areas for improvement within the engineering and construction sectors.

3.1.3. The Most Cited Articles Related to Stakeholder Management

Table 5 features articles on stakeholder theory, highlighting the importance of stakeholder collaboration and governance in EPC projects. The research by Qrunfleh et al. [26] and Bridoux et al. [27] discusses supplier collaboration and stakeholder governance, while Valentinov examines public sector relationships in Ireland.

Table 5. The most cited articles related to stakeholder management.

No.	Authors	Year	Title	Methods	Area	Results	Citations
1	Qrunfleh, S and Tarafdar, M [26]	2013	Lean and agile supply chain strategies and supply chain responsiveness: the role of strategic supplier partnership and postponement	Quantitative analysis: SEM and covariance analysis	USA	The results show that strategic supplier collaboration fully mediates the link between lean strategies and supply chain responsiveness, while postponement partially mediates agile strategies. A positive correlation exists between supply chain responsiveness and business performance, indicating companies should align supply chain practices with their strategy to enhance responsiveness and overall performance.	194
2	Wondirad, A; Tolkach, D and King, B [28]	2020	Stakeholder collaboration as a major factor for sustainable ecotourism development in developing countries	Qualitative analysis	Addis Ababa, the capital of southern Ethiopia, and three sites	The study shows that ecotourism in southern Ethiopia is underdeveloped and improperly expanding, neglecting the triple bottom line of economic, environmental, and social sustainability. The government prioritizes economic growth, focusing on revenue and tourist numbers over holistic environmental and community impacts, potentially overlooking negative socio-cultural and environmental consequences.	136

Table 5. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
3	Wang, ETG; Tai, JCF and Wei, HL [29]	2006	A virtual integration theory of improved supply-chain performance	Qualitative analysis	China–Taiwan	The results of the study show that virtual integration plays an important role in improving supply chain performance by enhancing manufacturing flexibility and cost advantage.	101
4	Bridoux, F and Stoelhorst, JW [27]	2022	Stakeholder governance: solving the collective action problems in joint value creation	Qualitative analysis	Global	The study's key results include the identification of three stakeholder governance forms—hub-and-spoke, lead role governance, and shared governance—and their comparative effectiveness in managing joint value creation activities based on complexity and dynamism.	66
5	Olsen, AO; Sofka, W and Grimpe, C [30]	2016	Coordinated exploration for grand challenges: the role of advocacy groups in search consortia	Probabilistic models and fixed-effect least squares models	Europe	The study shows that search coalitions, including advocacy groups, boost funding for proposed solutions by mitigating knowledge dispersion and aiding coordination. No significant link was found between project costs and funding likelihood, offering strategic guidance to governments, foundations, and coalitions on the positive role of advocacy groups.	62

Table 5. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
6	Quintana-García, C; Benavides-Chicón, CG and Marchante-Lara, M [31]	2021	Does a green supply chain improve corporate reputation? Empirical evidence from European manufacturing sectors	Quantitative analysis	Europe	The study's key results reveal that adopting green supply chain management practices, including environmentally focused supplier selection, monitoring, and ending partnerships based on ecological considerations, has a positive effect on corporate reputation.	61
7	Burke, Richard Demirag, Istemi [32]	2017	Risk transfer and stakeholder relationships in Public Private Partnerships	Qualitative analysis: semi-structured interviews	Ireland	The results of the study show that there is a positive and inclusive relationship between procurement agencies and special purpose vehicles (SPVs) in road PPP projects in Ireland, as well as partnerships between public sector agencies, which have important implications for risk allocation and management, as well as stakeholder relations.	44
8	Uribe, DF; Ortiz-Marcos, I and Uruburu, A [33]	2018	What Is Going on with Stakeholder Theory in Project Management Literature? A Symbiotic Relationship for Sustainability	Qualitative analysis	Global	Through descriptive and qualitative literature analyses, the study reveals the relationship between sustainable development, stakeholder theory, and project management. It identifies research trends and directions, highlighting an increasing number of articles on stakeholder theory and project management each year. This underscores the strengthening importance of meeting stakeholder needs as a strategic interdisciplinary focus.	32

Table 5. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
9	Valentinov, V and Hajdu, A [34]	2021	Integrating instrumental and normative stakeholder theories: a systems theory approach	Qualitative analysis	Global	The results show that the normative and instrumental types of stakeholder theory can be enhanced by the methodological guidance of systems theory, so as to improve its consistency with the complexity of modern society. This approach helps to address potential issues in stakeholder theory to make it better adapted to the complex environment of today's society.	16

In stakeholder theory research, the combination of qualitative and quantitative methods yields a well-rounded view of complex issues. Qualitative analysis explores stakeholder perspectives, while quantitative analysis reveals patterns and inter-relationships.

3.1.4. The Most Cited Articles Related to Procurement Management in Construction

Table 6 reviews the most cited articles on procurement management, with half addressing the topic globally. It discusses sustainable construction, project cost overruns, BIM and GIS integration, relationship management, and the role of trust in interface management, indicating directions for future research and current challenges.

Table 6. The most cited articles related to procurement management in construction.

No.	Authors	Year	Title	Methods	Area	Results	Citations
1	Pal, R; Wang, P and Liang, XP [10]	2017	The critical factors in managing relationships in international engineering, procurement, and construction (IEPC) projects of Chinese organizations	Quantitative research (logistic regression and neural network analysis methods were used in the analyses)	China	The article explores supplier and subcontractor relationships in international EPC projects, a largely underexplored area. It identifies four key success factors: supplier services, continuous improvement, delivery reliability, and problem-solving. The study suggests trust may be less crucial in IEPC projects and provides valuable insights for main contractors.	69

Table 6. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
2	Shen, WX; Tang, WZ; (...); Fang, J [12]	2017	Causes of contractors' claims in international engineering-procurement-construction projects	A combination of qualitative and quantitative methods	China	Contractor claims are primarily driven by external risks, owner behavior, and contract definitions, with owner behavior partially mediating the impact of external risks on claims, suggesting that such risks can indirectly influence claims through owner actions.	56
3	Shen, WX; Tang, WZ; (...); You, RC [14]	2017	Enhancing Trust-Based Interface Management in International Engineering-Procurement-Construction Projects	A combination of qualitative and quantitative methods	China	Trust impacts interface management performance both directly and by fostering inter-organizational openness and communication. Social network analysis shows varying influences of stakeholders in trust and interface networks. Grasping the links between trust, openness, and communication can enhance stakeholder coordination and interface management application.	48
4	Kabirifar, K and Mojtahedi, M [18]	2019	The impact of Engineering, Procurement and Construction (EPC) Phases on Project Performance: A Case of Large-scale Residential Construction Project	Quantitative research, TOPSIS	Iran	The study finds engineering design, project planning, and control as critical to project performance, with design being most influential, ahead of construction. Procurement is deemed even more crucial. Future research should aim to enhance these key elements and compare contractors' management practices for optimization.	40
5	Zhang, SR; Pan, F; (...); Wang, HX [35]	2017	BIM-Based Collaboration Platform for the Management of EPC Projects in Hydropower Engineering	Qualitative research	China	The BIM collaborative management platform addresses issues of information loss, silos, and ambiguity in traditional methods, boosting collaboration efficiency. It enhances the management of EPC hydropower projects, advancing both theoretical and practical aspects of the model.	38
6	Habibi, M; Kerman-shachi, S and Safapour, E [36]	2018	Engineering, Procurement, and Construction Cost and Schedule Performance Leading Indicators: State-of-the-Art Review	A combination of qualitative and quantitative methods	Global	Design changes are the primary cause of delays and cost overruns during engineering and construction phases. Resource shortages and price fluctuations significantly impact procurement performance. Additionally, adverse weather conditions, regulations, and inaccurate cost estimates are key factors affecting construction costs.	36

Table 6. *Cont.*

No.	Authors	Year	Title	Methods	Area	Results	Citations
7	Rudolf, CA and Spinler, S [15]	2018	Key risks in the supply chain of large scale engineering and construction projects	A combination of qualitative and quantitative methods	Global	Large-scale projects have a distinct supply chain risk portfolio compared with general projects, with behavioral risks being pivotal. Initial risk estimation in projects is often biased and underestimated. The study offers a systematic classification of supply chain risks in large-scale engineering projects.	32
8	Jo, SH; Lee, EB and Pyo, KY [37]	2018	Integrating a Procurement Management Process into Critical Chain Project Management (CCPM): A Case-Study on Oil and Gas Projects, the Piping Process	A combination of qualitative and quantitative methods	Korea	The study introduces a method applying critical chain project management (CCPM) in oil and gas projects, including a process flow chart for material management. The results indicate that CCPM reduces pipeline engineering construction time by approximately 35% compared with traditional methods. Neglecting material uncertainty can lead to a potential 5% increase in project schedule.	15
9	Hughes, W., Hillebrandt, P.M., Greenwood, D., & Kwawu, W. [38]	2006	Procurement in the Construction Industry	Qualitative research method	U.K.	The study explores procurement methods in construction, assessing their benefits and costs. It categorizes these methods and evaluates whether collaborative working procedures yield substantial business advantages. The research offers a detailed analysis of procurement processes, integrating relevant economic theories in the construction sector.	11
10	V. Koscheyev, A. Hakimov [39]	2019	Russian practice of using digital technologies in public procurement management in the construction industry	A qualitative research method	Russia	Digital technologies are reshaping public procurement in construction, replacing traditional government tools with innovative ones. Implementing electronic procurement tools requires synchronization at federal and market participant levels. These tools should facilitate online exchange of information and documents between buyers and sellers. Blockchain technology in Russian public procurement promises enhanced transparency and reliability.	6

3.2. Semantic Analysis Results

In the co-occurrence network for the keyword co-occurrence analysis, the color of the nodes represents the average duration (historical timeline) of each keyword's occurrence. Recently emerged keywords are depicted in lighter shades of yellow, while those that appeared earlier are represented in deeper shades of purple. This color scheme provides a visual representation of the temporal distribution of keywords within the analyzed literature. We created a bar chart to illustrate the publication timeline related to research on international engineering EPC project management, including topics such as EPC projects, supply chain integration, stakeholder theory, and procurement management, as shown in Figure 3. Research focused solely on EPC projects and supply chain management within individual international engineering contexts remains quite limited.

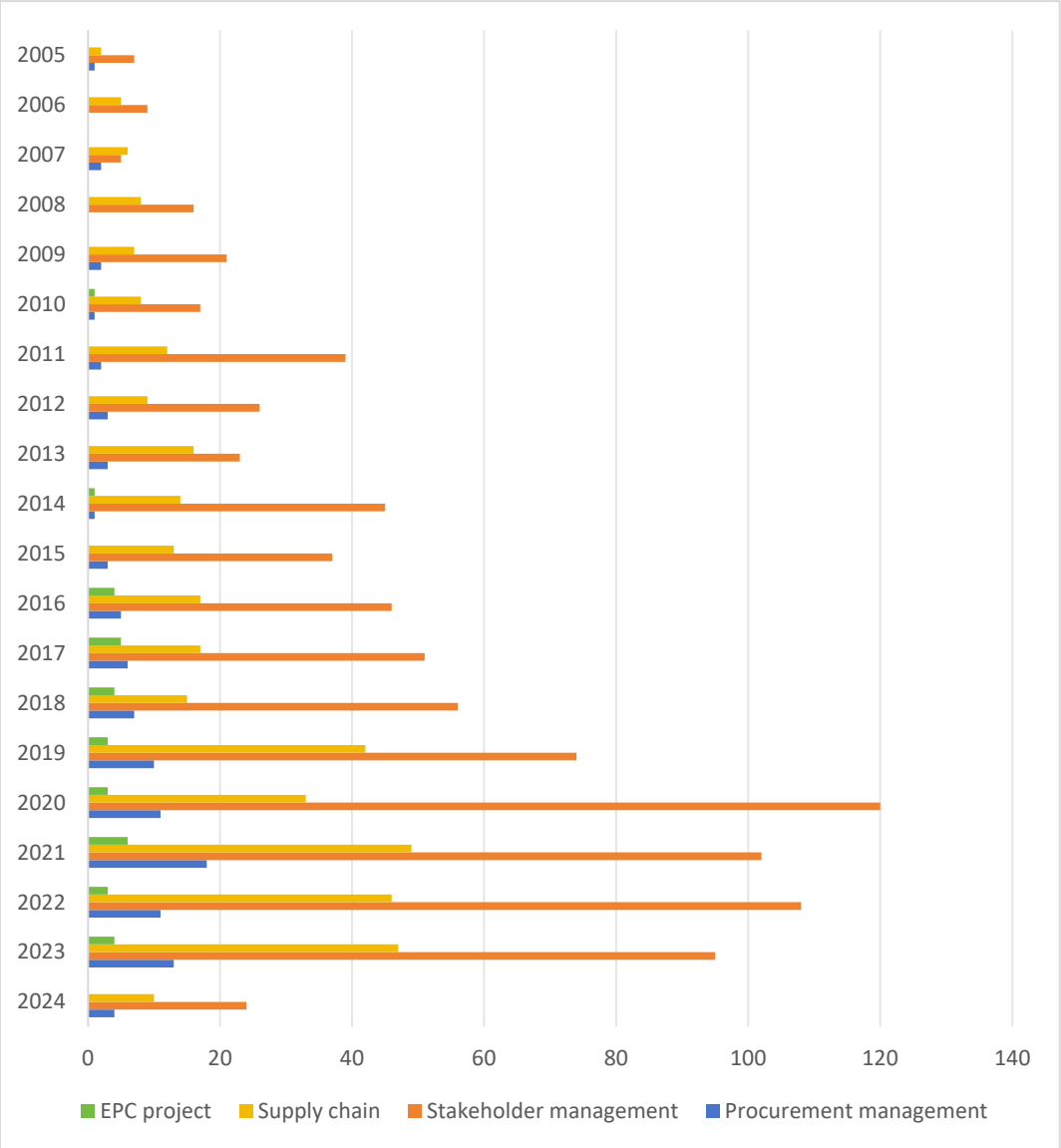

Figure 3. Publication distribution by years.

This breadth of terms reflects the field's scope, covering strategic, operational, and cross-border aspects of EPC projects. The network, using full counting, reveals frequent research clusters around EPC-related topics.

The empirical research has underscored the EPC model's efficiency over traditional construction methods. Konchar and Sanvido's influential study of 351 U.S. construction

projects revealed the EPC model's superior time and cost performance, with faster delivery by 33.5%, cost reduction of 5.2%, and duration decrease of 11.37%, without compromising quality.

The integrated design, procurement, and construction processes of the EPC model streamline project management, leading to its widespread adoption in international engineering. Standardized contracts by FIDIC, AIA, ICE, and the World Bank support this uniformity, despite the practical variability due to different project contexts.

However, EPC management faces challenges like scope definition, owner control over design, and contractor expertise demands. Research into these issues is crucial for improving project management, risk mitigation, and governance in international EPC projects.

Enhanced project management can elevate the EPC model's success, optimizing resources, ensuring timely delivery, maintaining quality, and achieving cost-effectiveness. Addressing these challenges will further establish the EPC model's efficacy in global engineering project execution.

Figure 4 presents a keyword co-occurrence network for EPC projects in international engineering, featuring 248 terms. Central keywords like "management", "performance", and "international EPC projects" highlight their pivotal role in the field's discourse. This network, with a threshold of two occurrences, includes 44 prominent keywords, offering a visual guide through the complex themes of EPC project management. These keywords are prominent in the co-occurrence analysis because they represent core themes extensively explored within the domain of EPC project management. The keyword "management" signifies that management practices are critical determinants of success in EPC projects; "performance" underscores the importance of project performance as a fundamental criterion for evaluating the effectiveness of EPC projects; and "international EPC projects" indicates that scholarly attention in this field is centered on the unique characteristics and challenges associated with international projects.

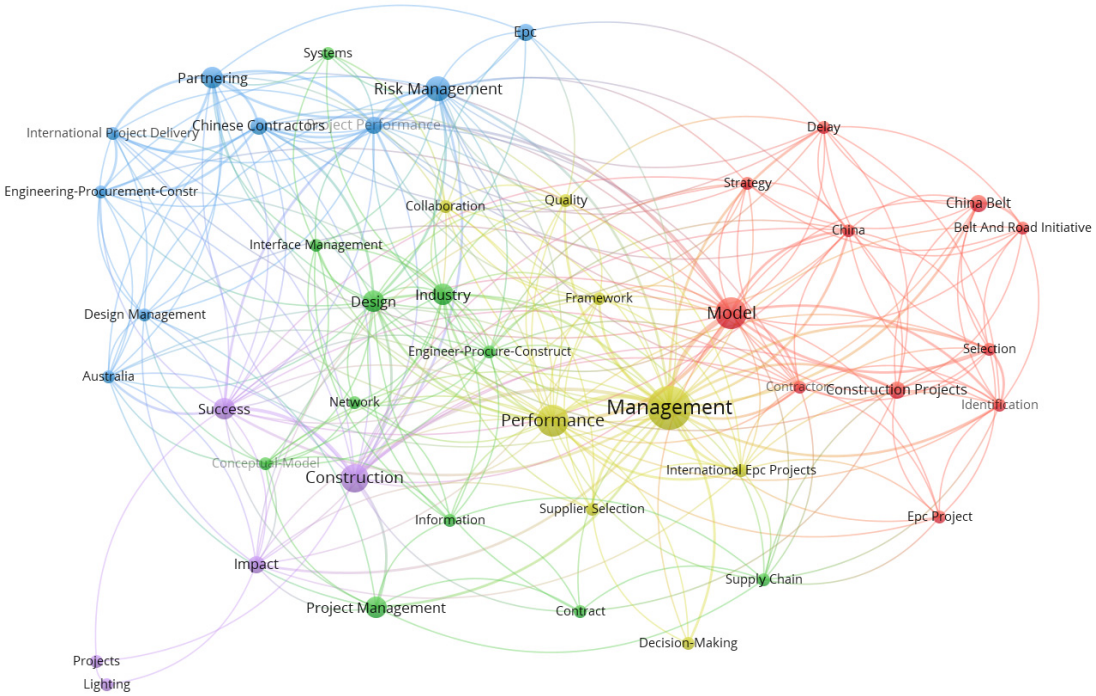

Figure 4. Co-occurrence network of research on international engineering EPC projects.

As is shown in Figure 5, in our detailed keyword co-occurrence network, we meticulously cataloged all pertinent keywords under the umbrella of supply chain integration, encompassing both author keywords and index keywords identified within the body of literature. The network showcases a rich tapestry of 173 interconnected keywords that

collectively represent the multifaceted nature of the topic. The network was methodically constructed using a full counting method, setting a threshold that required each keyword to appear at least twice to be included. In total, 25 keywords met this criterion and are featured within the network.

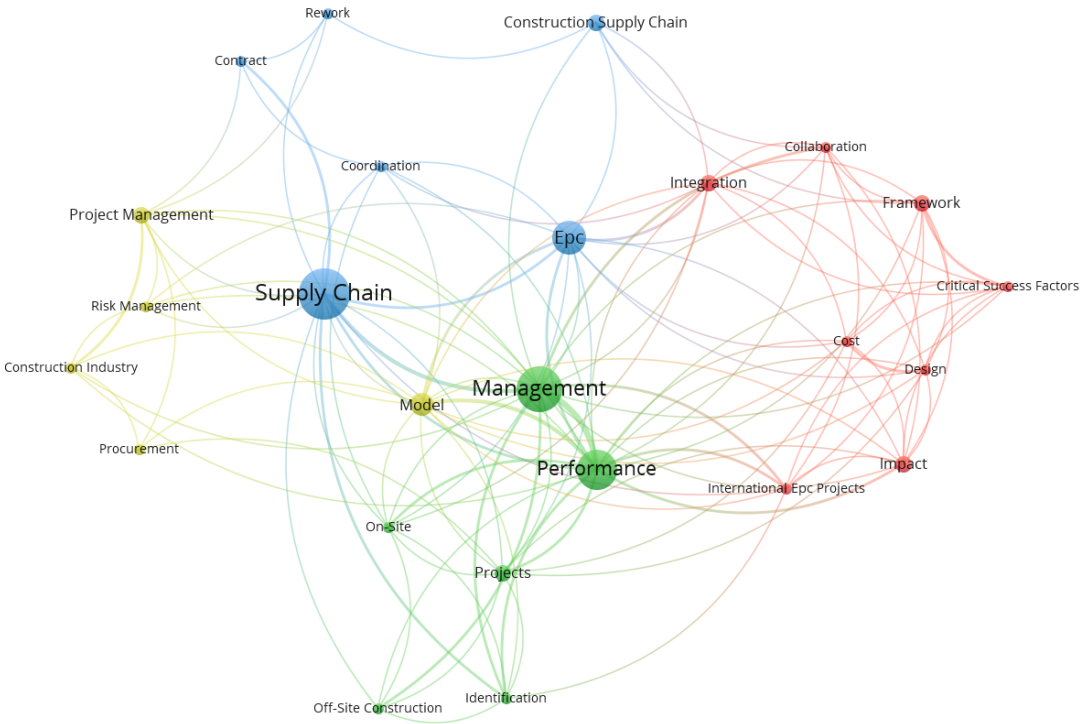

Figure 5. Co-occurrence network of research on the supply chain.

Figure 5 illustrates not only the keyword "supply chain" as a pivotal node but also other central research themes that resonate with the findings depicted in Figure 4. It highlights the core keywords pivotal to the discourse on supply chain integration management within the construction industry, mapping out the intricate web of relationships between them. The network reveals the primary focus areas of contemporary research, which include, but are not limited to, supply chain management, the EPC model, project management, performance enhancement, cost control, and the crucial elements of integration and collaboration.

The visualization in Figure 5 underscores the research community's concerted emphasis on the interplay between these key areas. It reflects a growing recognition of the critical role that seamless integration and strategic collaboration play in fortifying supply chain networks, particularly within the complex and dynamic environment of construction projects. The research accentuates the significance of harnessing effective management and coordination strategies to foster robust partnerships among supply chain stakeholders, with the ultimate goal of driving project performance to new heights and bolstering the likelihood of project success.

By delving into the nuances of these relationships and their impact on project outcomes, the network serves as a guide for scholars and practitioners alike, offering insights into the essential components that contribute to a resilient and high-performing supply chain. This, in turn, has profound implications for the development of best practices, the formulation of policies that support supply chain synergy, and the advancement of knowledge in the field of supply chain integration within the context of international engineering and construction projects.

Research also focuses on building management frameworks and identifying key success factors to further develop and optimize supply chain management in the construction industry. Since the 1980s, integration has been considered the essence of the supply chain,

serving as the source of organizational supply chain performance and competitive advantage, and thus has garnered significant attention both in research and in practice. There are many definitions of supply chain integration, but they generally share common themes. The definitions widely accepted from a theoretical perspective often involve interactions and collaborations at both internal and external levels [40,41].

At the level of internal integration, interaction represents the exchange related to activities between different departments; at the level of external integration, some scholars use the concept of "socialization" to represent the process of information flow within and outside organizations. Supply chain integration can be defined as the degree to which an organization engages in strategic cooperation and manages internal and external processes with its stakeholders to achieve efficient and rapid flow of products, services, information, capital, and decisions, ultimately providing the greatest value to customers at low cost and high speed [42,43]. The widely used definitions of supply chain integration include the following:

Bagchi et al. [44] propose that supply chain integration is the comprehensive cooperation of supply chain network members in strategic, tactical, and operational decisions, characterized by cooperation, information exchange, trust, partnerships, and a fundamental shift from managing individual functional flows to managing integrated process chains.

Flynn et al. [45] define supply chain integration as the degree to which firms engage in strategic cooperation and jointly manage internal and inter-organizational processes with supply chain partners.

Leuschner et al. [46] consider supply chain integration to be the scope and intensity of the links between firms in the supply chain process.

In the keyword co-occurrence network shown in Figure 6, all keywords related to stakeholders, including both author and index keywords, are tallied. These papers collectively feature 4939 keywords. The network was constructed using a full counting method with a threshold set at a minimum occurrence of five times. A total of 249 keywords met this threshold and were included in the network.

As depicted in Figure 6, keywords such as management, performance, and stakeholder engagement remain central within the network. Management and performance are core themes of the research, indicating that management practices and performance outcomes are key focal points in the study of stakeholder management. Sustainable development and innovation are significant research directions, indicating that researchers focus on how to achieve sustainability and innovation in projects through stakeholder management. Governance and conservation are important topics within stakeholder management, particularly in projects involving environmental and resource management. Project management and specific implementation strategies are key components in the research, involving how to effectively manage and coordinate stakeholders within a project.

For general contractors, the foundation of implementing supply chain integration is to establish partnerships with stakeholders that share risks and benefits. Since stakeholders are part of the external environment and are the source of the scarce and valuable resources needed by an organization, a key task for an organization is to improve relationships with stakeholders to fairly distribute resources, thereby achieving organizational goals [47]. The Project Management Institute defines stakeholder management as systematically identifying, analyzing, and planning related activities to communicate with stakeholders and influence them. The current research on stakeholders in the construction field mainly focuses on three aspects: key elements of stakeholder management, processes and methods of stakeholder management, and stakeholder relationship management.

In the 1980s, partnerships were first applied by the U.S. Army Corps of Engineers in the development and utilization of water resources in Alabama, and after achieving success, the concept was promoted worldwide. In recent years, partnership theory has been an international research hotspot, with its development divided into four stages: conceptual research, characteristic research, theoretical models, and empirical studies. Considering the actual situation of procurement management in international engineering EPC projects, it

is possible to recognize the necessity of conducting supply chain integration procurement management based on partnership theory in international engineering EPC projects.

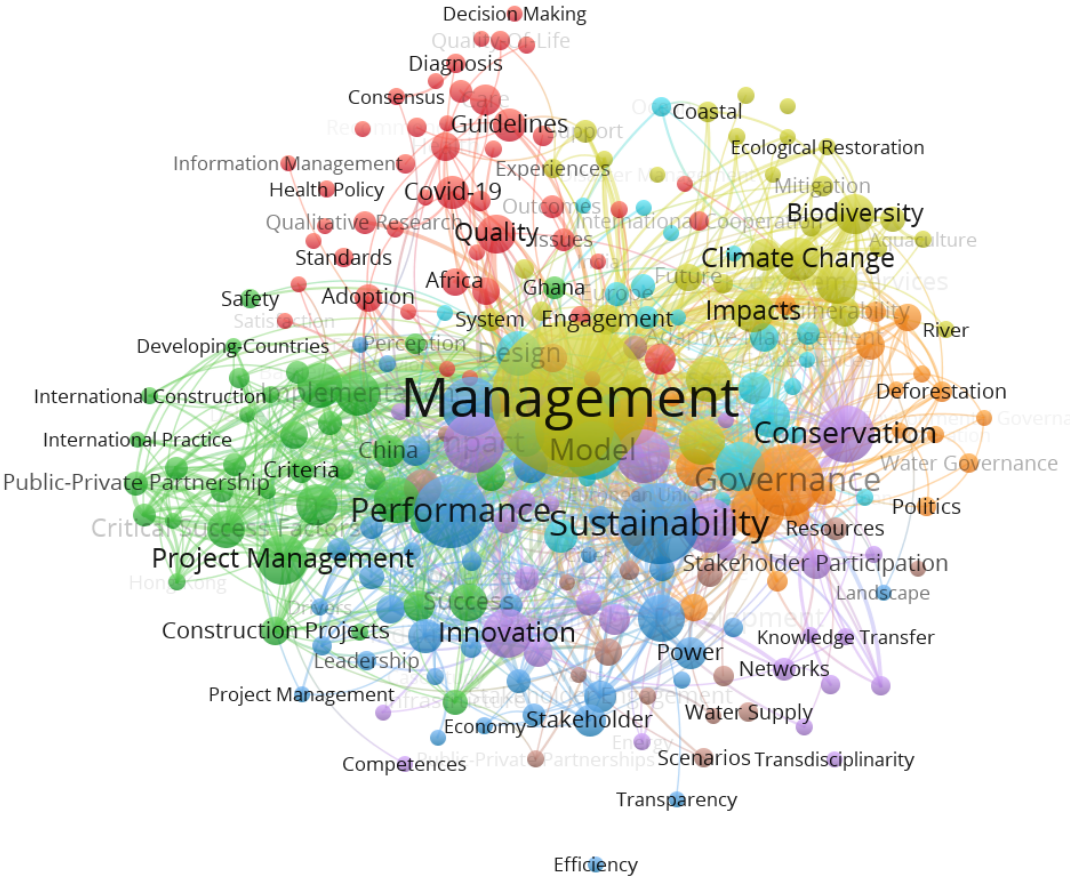

Figure 6. Co-occurrence network of research on stakeholder management.

Figure 7's keyword co-occurrence network, comprising 353 terms, reveals the thematic landscape of procurement management research. With a threshold of two occurrences, 62 keywords form clusters that reflect core research themes, color-coded for clarity.

The clusters range from design and decision-making (red), emphasizing strategic procurement planning, to EPC and supply chain optimization (green), risk management techniques (blue), BIM integration (orange), project management for procurement success (yellow), operational efficiency in construction (purple), and empirical case studies and knowledge organization (gray).

This network offers a panoramic view of procurement management, guiding researchers in identifying trends and areas for future study.

In international EPC projects, procurement is pivotal, linking design and construction, accounting for a significant contract value, and relying heavily on suppliers and logistics [48,49]. Challenges include communication with external parties, limited contractor control over long-lead items [50], and the procurement of non-standard parts without buffer stock [51]. Efficient procurement is crucial for project performance [52].

Procurement complexity arises from interdependent activities and stakeholder diversity [53,54], causing fragmentation and potential conflicts [52]. Global procurement faces unpredictable timings, especially for mechanical and electrical equipment, adding to the uncertainty [55]. The coordination of technical specifications among suppliers is also a challenge.

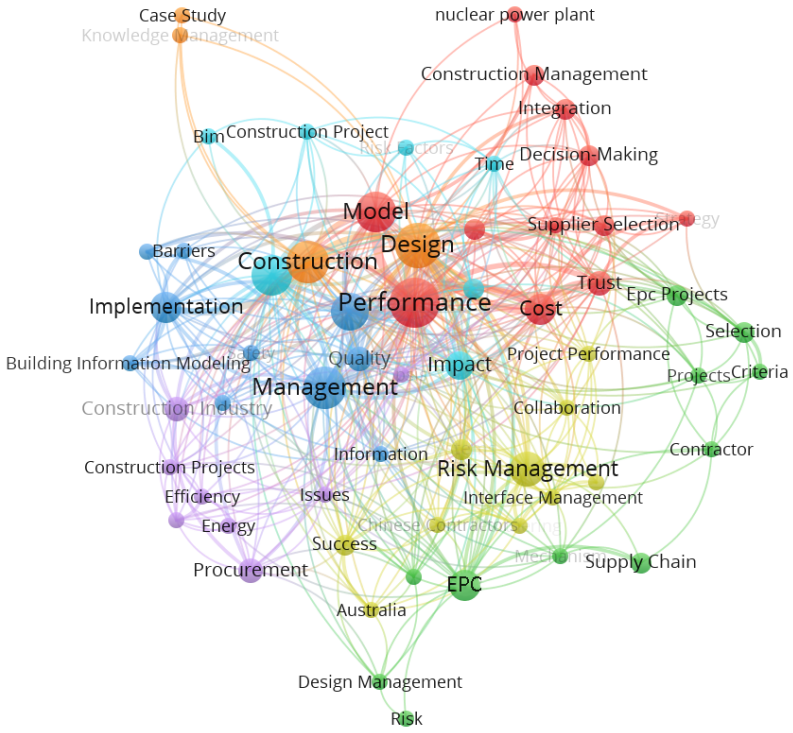

Figure 7. Co-occurrence network of research on procurement management.

3.3. Science Collaborations

Figures 8–11 present a comprehensive visualization of the literature coupling network of authors from our database, shedding light on the intricate web of co-authorship among scholars in the field of EPC (Engineering, Procurement, and Construction) projects within international engineering. In these figures, each solid circle symbolizes an individual author, with the circle's size being proportional to the number of research papers the author has contributed to. The connecting lines signify co-authorship links, with the thickness of each line denoting the frequency and strength of collaborations between pairs of authors.

To create a meaningful and focused network of collaborating authors, we established a weight threshold for inclusion, necessitating that the authors had a minimum count of published articles to their name. This threshold served as a filter to ensure that only authors with a significant presence in the field, as indicated by their publication count, were featured in the network. This strategic choice mirrors the approach taken with the keyword co-occurrence network and was designed to streamline the network, allowing for a concentrated view of the most influential and active research communities and individuals within the domain.

In conducting the co-authorship network analysis for research areas such as supply chain integration management, the application of stakeholder theory, and procurement management in the context of international EPC projects, we adopted a full counting method. This method permitted the inclusion of up to 25 authors per publication, reflecting the collaborative nature of research in this field. For publications specifically related to EPC projects, the threshold was set at a minimum of two papers per author, resulting in a network of 12 authors who met this criterion. In the case of supply chain integration, the same threshold of two papers per author identified 44 authors who qualified for inclusion. Similarly, for stakeholder theory, a minimum of two papers was required, with 107 authors reaching the threshold. Lastly, for the area of procurement management, a more inclusive threshold of at least one paper per author was applied, leading to a network comprising 170 authors who crossed this threshold.

These figures collectively map out the collaborative landscape of EPC project research, highlighting the most prolific authors and the strength of their academic partnerships. This

network analysis is instrumental in understanding knowledge within the field, as well as identifying key players whose work drives the research agenda in the complex and cross-disciplinary arena of international engineering projects.

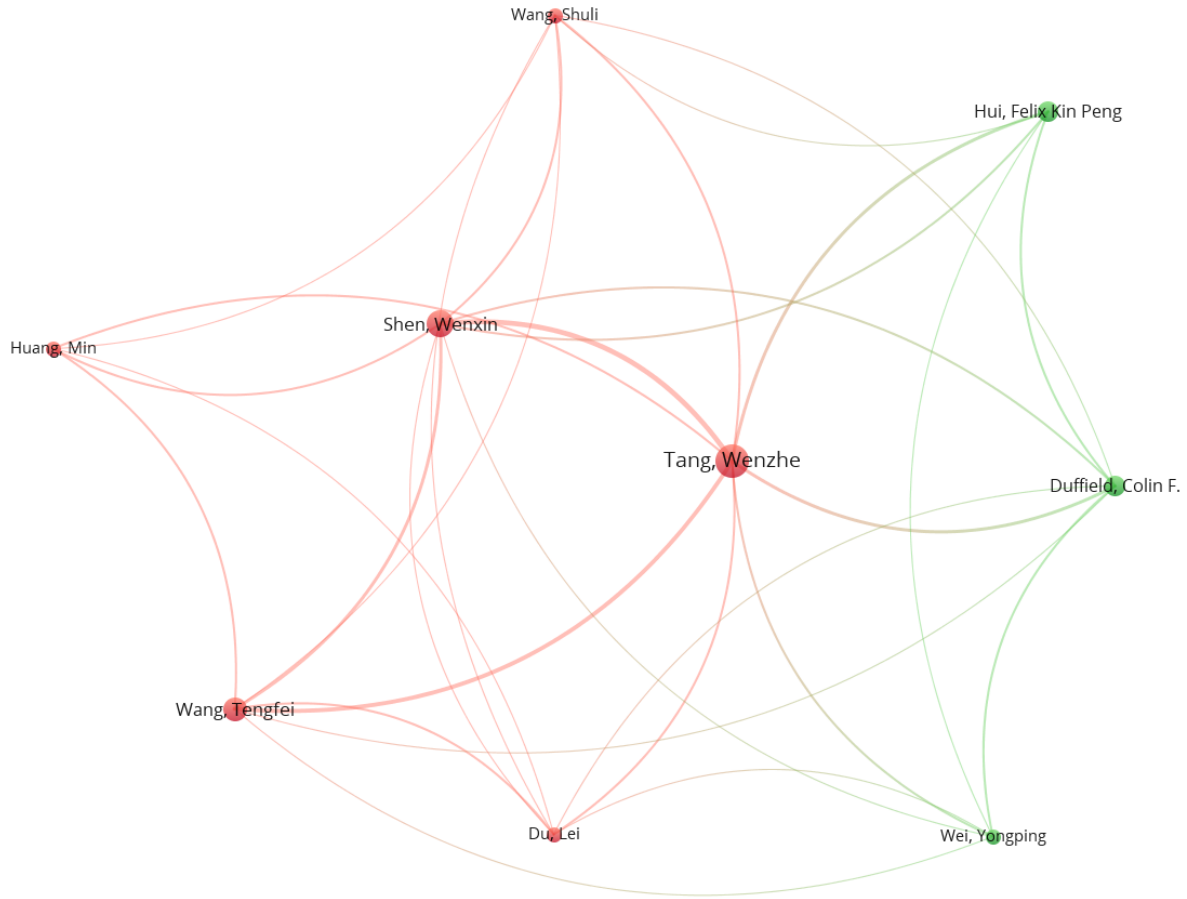

Figure 8. Co-authorship network of research on EPC projects.

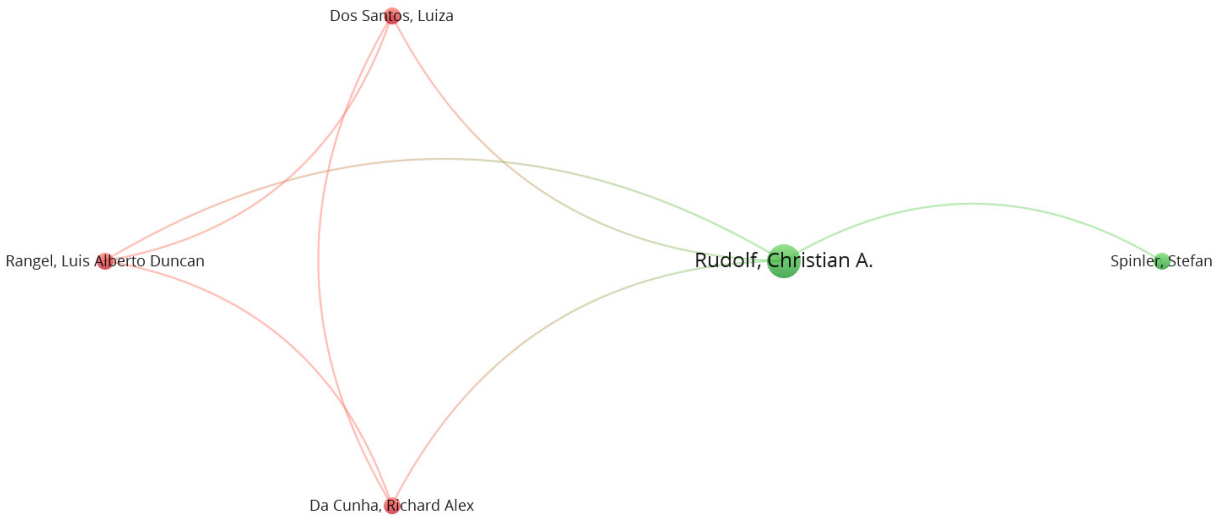

Figure 9. Co-authorship network of research on the supply chain.

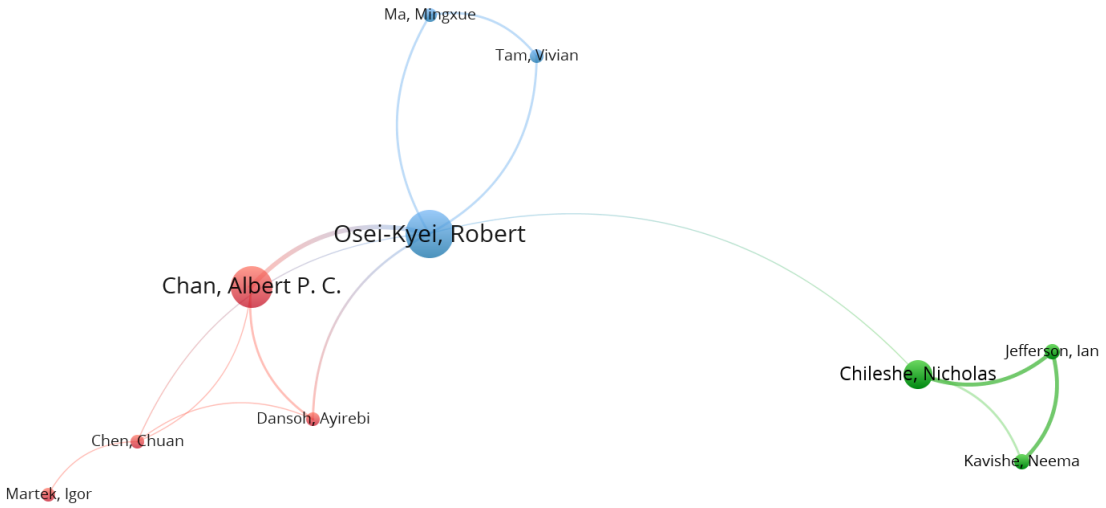

Figure 10. Co-authorship network of research on stakeholder management.

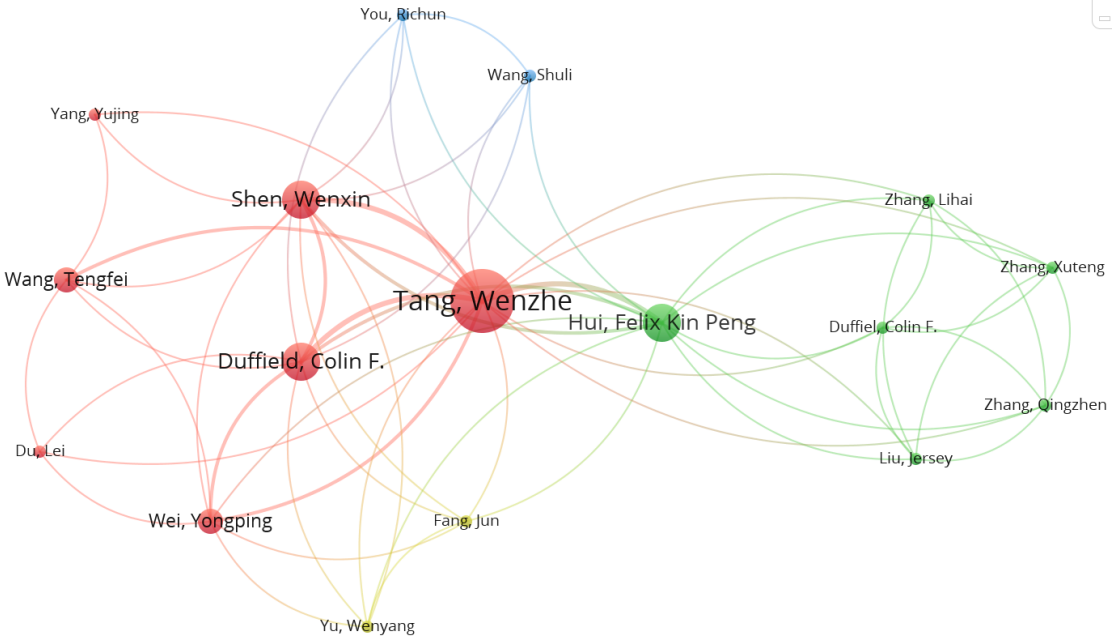

Figure 11. Co-authorship network of research on procurement management.

As shown in Figure 8, within the co-authorship network of research in EPC projects in international engineering, research teams revolve around Tang, Wenzhe [12], who is a central author in the co-authorship network, demonstrating significant influence in the field of EPC projects. Tang, Wenzhe [12] is the author with the highest number of published documents, totaling seven, and has accumulated 264 citations, with a total link strength of 23, indicating his importance in the research domain. Shen, Wenxin [12] published five documents, with a cumulative total of 204 citations and a total link strength of 18, also displaying substantial research impact. Duffield, Colin F. and Hui, Felix Kin Peng [12] each published three documents, with cumulative citation counts of 152 and 112 and total link strengths of 12 and 9, respectively. Authors with higher link strengths often play pivotal bridging roles in the network, facilitating communication between different research directions and researchers.

Tang, Wenzhe [12] and colleagues aimed to quantitatively and systematically study how trust, openness, and communication are inter-related to improve performance in interface management within international EPC projects. Data were collected through surveys

and interviews to develop and test a conceptual model. Path analysis indicated that trust can not only directly promote interface management but can also have a positive impact on interface management by enhancing inter-organizational openness and communication. Social network analysis visualized the industrial relationships of contractors, revealing the different impacts that stakeholders have within the trust and interface networks of international EPC contractors.

As illustrated in Figure 9, the co-authorship network for research on supply chain integration management features a prominent red cluster, which includes Tang, Wenzhe [14] and colleagues as key contributors. Their research delves into critical aspects of relationship management, trust, and interface management within the context of international Engineering, Procurement, and Construction (IEPC) projects. Shen, Wenxin [14], alongside Tang, Wenzhe [14], underscores the pivotal role of trust in IEPC projects in their studies and articulates strategies to bolster trust among project participants. This emphasis on trust is congruent with the dense collaborative ties observed within the red cluster, reflecting a concerted effort and substantial scholarly output in this specialized area of research. These authors have directed their investigative efforts toward the nuances of relationship management, risk mitigation, and the overarching project management dynamics that are central to effective supply chain integration.

The network also identifies a green cluster led by Duffield, Colin F. [14], where the research is particularly concentrated on enhancing project performance and managing risks within the supply chain. The collaborative work of Hui, Felix, Kin Peng, and Duffield, Colin F. [14] underscores the importance of integration and collaboration in supply chain management. Their research offers insights into how fostering collaborative relationships and facilitating information sharing among supply chain members can lead to significant improvements in project outcomes. This focus on collaborative synergy aligns with the interconnectedness of the green cluster, showcasing their joint research endeavors and the contributions they have made to the field.

The research outputs from these authors extend into exploring the integration and collaborative mechanisms within the supply chain, with the aim of advancing project performance through improved management practices. Their work often involves developing and testing theoretical models, conducting empirical studies, and applying advanced analytical techniques to understand the complex interplay between various supply chain entities. By doing so, they contribute to the body of knowledge on how to effectively manage the intricate web of relationships and processes that define supply chain integration in large-scale international EPC projects.

Overall, the detailed analysis of the co-authorship network in Figure 9 reveals a landscape of academic collaboration that is both rich and dynamic, highlighting the key researchers and their interconnected efforts to push the boundaries of supply chain integration management within the challenging and globally distributed environment of international engineering projects.

Within the red cluster, the authors are deeply engaged in investigating the intricate dynamics of relationship management, the cultivation of trust, and the strategies for risk management, all within the sphere of supply chain integration management. Their research probes into how these factors interconnect to influence the efficacy of supply chain operations and the successful delivery of projects. Shen, Wenxin and Tang, Wenzhe [14] are pivotal figures in this cluster, with their work providing valuable insights into the mechanisms through which trust can be established and maintained in the complex environment of IEPC projects. They explore the multifaceted nature of trust, examining its impact on collaboration, risk sharing, and overall project governance.

On the other hand, the green cluster's authors direct their scholarly attention toward optimizing project performance and delving into the critical components of supply chain integration and collaboration. Their research encompasses an array of topics, from the development of integrated supply chain frameworks to the analysis of collaborative networks that enhance operational efficiency and drive project success. Hui, Felix, Kin Peng,

and Duffield, Colin F. [14] stand out in this cluster for their collaborative work that has significantly contributed to the understanding and advancement of integrated supply chain management. They examined how synergistic practices and information sharing among supply chain members can lead to improved project performance metrics and a more cohesive project management approach.

The work of these authors, particularly within their respective clusters, is characterized by methodological rigor and a commitment to advancing theoretical and practical knowledge in supply chain integration. They conduct empirical research, develop theoretical models, and engage in case study analyses to provide evidence-based recommendations for managing the complex web of stakeholder relationships and processes that are inherent in international EPC projects. Through their contributions, they have helped to shape the discourse on supply chain integration, offering strategies for overcoming the challenges associated with managing large-scale, multi-faceted projects in a globalized context.

In summary, the detailed examination of the red and green clusters within the co-authorship network reveals a collaborative academic landscape where key researchers understand supply chain integration management. They address critical questions on how best to manage relationships, build trust, manage risks, and foster collaboration to achieve superior project outcomes in the demanding realm of international engineering and construction.

As depicted in Figure 10, the co-authorship network for stakeholder theory research in international engineering projects demonstrates a nascent but growing body of work. Within this network, a few key authors stand out for their contributions to the field.

Osei-Kyei's [56] research delves into the nuances of stakeholder management, advocating rates by advocating for equitable stakeholder benefit distribution and effective management practices. His work often explores frameworks and strategies designed to engage stakeholders proactively and ensure that their interests are adequately represented and managed throughout the project lifecycle.

Chileshe's [57] focus on knowledge management and risk management in construction and project management highlights the critical role that systematic knowledge sharing and comprehensive risk assessments play in project success. His research emphasizes the need for robust knowledge management systems that facilitate the capture, storage, and dissemination of project-related information, thereby enabling better decision-making and risk mitigation.

Chan [58] makes significant inroads in the areas of project management and construction management, with a special emphasis on project risk management and the development of stakeholder strategies. His work often involves identifying potential risks early in the project and developing contingency plans, as well as understanding the complex web of stakeholder interests and how they can be aligned with project objectives.

Dansoh [59] focuses on the aspects of collaboration and communication within project management, underscoring the vital importance of teamwork and the sharing of information for project success. His research suggests that effective communication channels and collaborative practices are essential for synchronizing efforts among various project teams and stakeholders, thereby facilitating a more integrated and cohesive approach to project execution.

Collectively, these authors contribute to a broader understanding of how stakeholder theory can be applied to enhance project and supply chain management outcomes. Their work underscores the importance of collaborative efforts, effective communication, and the adoption of technological tools in navigating the complex stakeholder landscapes typical of international EPC projects. By integrating stakeholder perspectives into the management process, these researchers provide valuable insights into achieving more efficient, effective, and successful project delivery in the challenging context of global engineering endeavors. Their contributions not only advance academic knowledge but also offer practical implications for industry professionals seeking to optimize stakeholder engagement and project performance.

The co-authorship network for procurement management depicted in Figure 11 showcases a notable research team dedicated to this theme. The red cluster primarily focuses on relationship management, risk management, and trust management, with core authors such as Tang, Wenzhe and Shen, Wenxin [14]. Authors in this cluster demonstrate a tight-knit collaborative relationship, mainly concentrating on areas such as supply chain management, project management, risk management, and trust management. Tang, Wenzhe and Shen, Wenxin [14], in particular, have a substantial body of collaborative research within this domain, covering key management factors in international Engineering Procurement and Construction (IEPC) projects. Wei, Yongping and Wang, Tengfei [13] have also been involved in several collaborative projects, mainly concerning how to enhance project performance through improved management practices.

The green cluster is focused on supply chain integration and collaborative management, with core authors including Hui, Felix Kin Peng and Duffield, Colin F [14]. This cluster emphasizes the importance of integrated processes and teamwork within the supply chain, and how these can contribute to the overall efficiency and success of projects.

The blue cluster represents a more independent set of collaborative relationships, with main authors such as Wang, Shuli and You, Richun [14]. The work within this cluster likely addresses specific aspects of procurement management, possibly including innovative procurement strategies, contract management, and the integration of new technologies into procurement processes.

Overall, the network in Figure 11 illustrates the collaborative efforts and intellectual contributions of researchers in the field of procurement management, highlighting the interconnectedness of their work and the collective impact it has on advancing knowledge and practices in the procurement of international engineering projects.

4. Discussion

This study provides a bibliometric review of the international engineering contracting market, with a focus on the Engineering, Procurement, and Construction (EPC) model, procurement management, and supply chain integration. International EPC projects are complex, involving substantial financial investments and numerous stakeholders. Effective procurement, including supplier selection and contract management, is crucial for project success, as emphasized by Pal et al. [10] (2017), who highlight the importance of quality services from suppliers and subcontractors. This study highlights the gap between theory and practice in the application of supply chain integration within international EPC projects. It also provides a detailed examination of the co-occurrence network of key terms in EPC project management. This analysis helps the academic community understand why "management" and "performance" are dominant themes in EPC projects and what this means for future project management research.

Our findings align with the existing research that underscores the significance of supply chain integration for EPC project performance. For instance, Frank et al. [56] demonstrate how digital platforms can enhance efficiency, while Flynn et al. [57] identify uncertainties within the supply chain that can be mitigated through integrated IT systems. However, this study extends these findings by providing a comprehensive analysis of how specific supply chain integration strategies can improve project outcomes, thus highlighting the novel contribution of our work to the existing body of literature.

Moreover, while Bridoux and Stoelhorst [13] explore governance models for stakeholder value creation, this study explicitly addresses the gaps in research related to supply chain maturity and risk management in large-scale EPC projects. Our research suggests that the current literature predominantly discusses theoretical frameworks, whereas practical applications of supply chain integration in construction remain underexplored.

We also find that flexibility is essential for construction supply chain management to meet project-specific demands. As noted in the literature, real-time information is key to managing stakeholder interactions [60]. Our study advocates innovative approaches

to overcome contemporary procurement challenges and effectively manage stakeholder interests [61].

Enhanced supply chain integration is imperative for international EPC contractors to leverage the resources of procurement stakeholders [5,60]. This research aims to guide contractors in adopting advanced supply chain management techniques within procurement processes for international EPC projects, thereby improving both project efficiency and economic performance.

The implementation of advanced supply chain management solutions is critical for enhancing project efficiency and financial results in global EPC contexts [62]. Our findings suggest that these strategies facilitate resource optimization, streamline procurement procedures, and foster collaboration among diverse stakeholders [63]. By maximizing these elements, EPC contractors can ensure timely project completion and improve overall performance, which is vital in today's competitive construction landscape [64].

Furthermore, as the construction industry grapples with escalating environmental concerns, integrating procurement strategies aligned with sustainability principles becomes increasingly vital. This alignment not only promotes judicious resource use but also mitigates ecological impacts [65]. By prioritizing sustainable practices—such as utilizing eco-friendly materials and energy-efficient technologies—contractors can meet regulatory requirements while enhancing their reputations and attracting environmentally conscious clients [66].

To effectively assess the readiness of international construction projects to adopt sustainable supply chain management practices, it is essential to analyze the multidimensional impacts of these practices on economic, environmental, and social sustainability. The implications presented in Table 7 elucidate key outcomes across these dimensions, highlighting the interconnectedness of sustainable practices within the supply chain and their broader implications for sustainable development in international construction projects.

Table 7. Implications of sustainable supply chain management practices in international EPC projects.

Outcome	Implications for Economic Sustainability	Implications for Environmental Sustainability	Implications for Social Sustainability
Enhanced Supply Chain Transparency	Reduction in costs and improvement in operational efficiency	Minimization of resource waste and promotion of eco-friendly materials	Strengthening stakeholder trust and improving collaborative relationships
Collaboration and Information Sharing	Lower transaction costs and increased innovation capacity	Enhanced environmental management and reduced carbon footprint	Promotion of fair trade and increased employee satisfaction
Optimized Supplier Selection Criteria	Establishment of long-term partnerships and risk mitigation	Encouragement of renewable resource utilization and pollution reduction	Support for local economies and enhancement of social responsibility
Improved Performance Evaluation Systems	Strengthened performance management and increased financial returns	Enhanced environmental performance and promotion of sustainable practices	Increased employee engagement and sense of community identity
Robust Risk Management Framework	Decreased economic losses and enhanced project resilience	Reduction in environmental risks and prevention of ecological incidents	Heightened community safety and promotion of social harmony

This analysis underscores the importance of customized solutions that address the unique challenges faced in the EPC sector, enhancing the prospects of success for international projects. The application of sustainable supply chain management principles not only improves operational efficiency but also fosters collaboration, innovation, and social responsibility. This comprehensive approach is crucial for meeting the rising expectations for sustainability in construction while ensuring economic viability.

In acknowledging the limitations of this study, we recognize that the current analysis primarily relies on the existing literature, which may not encompass the full range of practical applications in the field. Further empirical research is necessary to deepen our understanding of the effective implementation of sustainable supply chain principles within international EPC projects. Future studies should explore emerging technologies, such as big data analytics, to identify and mitigate supply chain challenges. Aligning supply chain strategies with sustainable development goals empowers stakeholders in the construction sector to enhance project outcomes, strengthen resilience, and promote a more sustainable future. This holistic approach is not only essential for addressing the pressing demands of multinational construction projects but also for advancing accountability and sustainability within the industry.

5. Conclusions

The bibliometric analysis and review in this study reveal a significant gap between theoretical research and practical application of supply chain management (SCM) in international EPC projects, particularly in terms of supply chain maturity and cross-cultural management. Moreover, there is a lack of in-depth research on how to optimize supply chain integration under different legal and regulatory frameworks Future research should specifically investigate how the integration of sustainability into supply chain practices can foster innovation and establish lasting relationships among stakeholders. This examination could yield valuable insights into optimal strategies for collaboration and resource sharing, thereby facilitating the achievement of overarching global sustainability goals. By addressing these factors, EPC contractors can ensure the economic viability of their operations while maintaining environmental and social responsibility, ultimately contributing to a more sustainable future in engineering contracting [67].

Our analysis reveals significant trends in the development of international EPC projects, underscoring the need for further research on supply chain maturity and risk management. While supply chain integration has proven successful in manufacturing, its application in construction, particularly in the international EPC context, remains underdeveloped. Future studies should focus on adapting insights from manufacturing to the unique characteristics of the construction sector, thereby creating flexible integration strategies tailored to specific project needs.

Construction supply chains are inherently project-specific and temporary, necessitating adaptable management tools. Research should prioritize the development and practical application of such tools to enhance their relevance within the construction industry [68].

Cross-cultural challenges in international EPC projects also warrant thorough investigation. Future research should explore the impact of cultural differences on supply chain management and procurement practices, drawing upon multinational case studies to provide comprehensive insights.

Moreover, aligning supply chain practices with diverse legal frameworks is essential for the smooth execution of international EPC projects. Addressing the reluctance of companies to share sensitive data is critical; potential solutions may include fostering partnerships or employing anonymized data [68].

Broad empirical research extending beyond theoretical exploration is essential to better assess the applicability of findings in the construction industry. Innovative methodologies, such as big data analytics, could offer fresh perspectives on supply chain challenges and enhance decision-making processes.

Tailoring theoretical frameworks to reflect the project-based nature of the construction industry will further guide effective supply chain optimization. Addressing these gaps will enhance the relevance of scholarly work, equipping EPC managers with practical tools for global supply chain management and improving project efficiency and success in the international arena.

To augment the relevance of our findings, it is crucial to correlate insights on supply chain management in multinational EPC projects with the principles of sustainable development. The construction sector is under increasing pressure to mitigate its environmental impact; thus, integrating sustainable practices into supply chains can enhance project efficiency and ensure long-term profitability. Future studies should focus on the successful incorporation of green technologies and sustainable procurement practices into supply chain strategies, ensuring that multinational EPC projects align with global sustainability objectives. By addressing these critical factors, scholars and practitioners can strengthen the resilience and responsibility of the construction sector, ultimately promoting a balance between economic development and environmental stewardship.

In conclusion, this study highlights the vital importance of efficient procurement and supply chain integration in the successful implementation of multinational Engineering, Procurement, and Construction (EPC) projects. The complexity of these projects, characterized by substantial financial commitments and multiple stakeholders, necessitates the adoption of effective supply chain management solutions. The current literature emphasizes the necessity of cultivating enduring relationships with suppliers and enhancing information exchange, both of which are crucial for fostering collaboration and mitigating risks. The ongoing evolution of the construction sector reinforces the need for integrating innovative supply chain management strategies to optimize procurement processes and improve overall project efficiency.

Furthermore, in light of the pressing challenges facing the construction industry, the integration of sustainability principles into supply chain practices is essential. By adopting procurement strategies that prioritize sustainable materials and energy-efficient technologies, EPC contractors can bolster their competitive advantage and attract environmentally conscious clients, thereby aligning with regulatory standards. Future research should investigate how the incorporation of sustainable practices can drive innovation and foster lasting partnerships among stakeholders, ultimately aiding in the achievement of global sustainability goals. By addressing these fundamental criteria, EPC contractors can ensure the economic sustainability of their operations while fulfilling their social responsibilities, thereby promoting a more sustainable future in engineering contracting.

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Acronymous

TS	title search
ABS	abstract
KEY	key words
EPC	Engineering, Procurement, and Construction
SCM	supply chain management
FIDIC	International Federation of Consulting Engineers
AIA	American Institute of Architects
ICE	Institution of Civil Engineers

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