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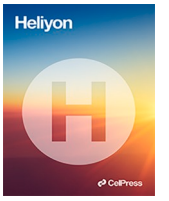

The scientometric analysis and visualization of sustainable procurement

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ABSTRACT

Sustainable procurement has emerged as a crucial strategy to address environmental and social challenges while promoting responsible sourcing and procurement practices. This research presents a comprehensive scientometric analysis and visualization of 1044 publications from 1997 to July 2023 through a co-author, co-word, and co-citation analysis on sustainable procurement from the Scopus core collection database using VOSviewer and Gephi software. Prominent research areas include green procurement, sustainable procurement, sustainability, procurement, and supply chain. Leading institutions are the University of Southern Denmark, European Business School (EBS) University, Germany and the University of Louvain, Belgium, with the United Kingdom, United States, and China as citation leaders. The Top sustainable procurement outlets are the Journal of Cleaner Production, the International Journal of Production Economics, the Journal of Business Ethics, Sustainability, and Supply Chain Management. By providing a holistic overview of the sustainable procurement research landscape, this study contributes to evidence-based decision-making and fosters a collaborative approach towards achieving a more sustainable and socially responsible world essential for facilitating sustainability efforts. The findings serve as a foundation for future research and policy development, facilitating knowledge exchange and driving positive change in procurement practices.

1. Introduction

Procurement can be seen as a process of obtaining various products and services for a construction project based on pre-determined standards [1]. [2], tend to shed light on its definition, implying procurement to be the basic process within any construction process that tends to source, purchase and provide knowledge as well as labour, equipment and administration necessary for accomplishing the set goals of a project. Sustainable procurement, on the other hand, speaks of the application of the concepts within the sustainable development goals to procurement practices to achieve a safer, much more habitable planet which enhances a better life quality while considering an organization's production and consumption practices [3,4]. Furthermore, Sustainable procurement has emerged as a critical practice in today's construction industry, going well beyond the basic purchase of goods and services [5], it is referred to as green procurement or eco-procurement, involves acquiring goods and services in a manner that maximizes benefits for an organization while minimizing adverse impacts on the environment, society, and the economy [6]. Although sustainable procurement and sustainability are intertwined, there appears to be a lingering difference between the two. According to Ref. [7], the area of procurement contributes immensely to the implementation of the sustainability concept within the business environment majorly because of the process of procurement which kick-starts the material flow and service delivery within companies. Specifically, individual

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organizations are only as sustainable as their supply chain [8,9]. Hence sustainability is keenly focused on supply within construction while sustainable procurement has its anchor on purchase. Therefore, various organizations with the target of being sustainable must start with the supply chain while establishing various environmental and social standards with the suppliers within this chain [10,11] before the procurement chain is established. The application of the sustainability concept within the construction industry thus requires the active implementation of a sustainability concept within the procurement process [12]. Sustainable procurement awareness is important in four areas as it helps to reduce the influence of procured goods, services and works within the entire supply chain life cycle; it also aids in decreasing the funding used through purchase upgrades and enhancement, product re-use and recycling amongst others; it further aids and creates a growing need in the sustainability ecosystem and the sustainable procurement process; it finally enhances good purchasing and procurement of products and services ensuring that supply chain meets the required ethical and environmental standards [13,14].

Sustainable procurement, an essential component of sustainable development, has garnered increasing attention in recent years due to growing concerns about environmental degradation, social responsibility, and resource efficiency. As businesses and organizations recognize the need to address their environmental and social impacts, sustainable procurement emerges as a critical strategy to ensure responsible sourcing and procurement practices that align with broader sustainability objectives. Scientometric analysis and visualization serve as powerful tools to gain valuable insights into the evolution and current state of sustainable procurement research. By applying scientometric techniques, researchers can identify key themes, influential authors, and important publications, providing a comprehensive understanding of the research landscape in sustainable procurement. This research embarks on a scientometric journey to investigate the growth and development of sustainable procurement research from 1997 to July 2023. By leveraging data from the reputable Scopus database, a comprehensive analysis was conducted to understand publication trends, thematic clusters, and collaborative networks. Furthermore, the study aims to uncover influential authors and publication sources, shedding light on the key contributors shaping the field's advancement. This research seeks to unravel the multidimensional aspects of sustainable procurement research, showcasing the collective efforts of researchers, institutions, and countries in driving positive change. By embracing scientometric analysis and data visualization techniques, this study will offer a comprehensive and objective evaluation of the research landscape, providing valuable insights for stakeholders committed to creating a more sustainable and socially responsible world.

2. Research methodology

The research methodology was created to include the following steps: selecting the scientific mapping tools; collecting, processing and analysing the data; visualizing the results; and presenting, understanding, and debating the results.

2.1. Data collection

The most popular databases that index journals are Web of Science and Scopus [15]. Some studies, like [16], have only ever used Scopus as a database. The justifications given here, that the Scopus database was chosen due to its greater coverage, are sufficient, thus, this study used the Scopus database only to extract the bibliographic information for the research. The article type included conference papers, articles, conference reviews, book chapters, books, reviews and notes. The following retrieval code was used in the Scopus database: ("sustainable procurement") OR ("green procurement") OR ("sustainable sourcing") OR ("conscious procurement") OR ("eco-friendly procurement"). "TITLE-ABS-KEY" means an article title, abstract, and keywords. When the defined phrases appeared in the title, keywords, or abstracts, the linked publication would be recognised, ensuring that the data is as thorough as feasible. To exclude irrelevant publications, a human examination of search results was used. Furthermore, the search was also limited to publications that had been published from 1997 to July 9, 2023, 1044, publications were retrieved from the Scopus database. However, there may be a subsequent increase in those data sets by the end of the year 2023.

2.2. Science mappings Techniques and tools

Science bibliometric mapping shows the spatial relationships between authors, specific publications, specialities, fields, and disciplines [17]. To firmly establish the evolution and cognitive structure, it needs to analyse delimiting research and scientific domains [18]. The study employed three scientometric techniques: (i) co-author analysis, which detects collaborations among authors, countries, and institutions [19,20]; (ii) co-word analysis, which examines the co-occurrence of keywords or terms [21]; and (iii) co-citation analysis, which identifies authors, articles, and journals that are frequently cited together [22,23]. For visualizing and presenting the findings, VOSviewer and Gephi were the science mapping tools of choice. VOSviewer, developed by Ref. [24], provides essential functionality for constructing, visualizing, and navigating bibliometric networks. On the other hand, Gephi, a popular open-source application created by Ref. [25], enables comprehensive exploration and visualization of various graphs and networks, leading to a better understanding of the displayed data.

2.2.1. Data processing

In the research, various network analyses were conducted to gain insights into the field of sustainable procurement. First, keyword networks were generated using VOSviewer, highlighting crucial keywords within the study and their relevance to key themes. the term "keyword" was selected as the type of analysis with "fractional counting" selected as the counting method. The "minimum number of occurrences" a keyword must have to be included in the network was set at '10'.

Next, a co-authorship network was created using VOSviewer to uncover researchers' interests in sustainable procurement and its

components. For the co-authorship analysis, the word “co-authorship” was selected as the analysis type with “fractional counting” being the applied method of counting. Applied to the analysis, the “minimum number of documents for an author” was set to ‘4’ and the ‘minimum number of citations of an author” was also set to ‘4’ which; entailed that the author should have been cited at least ‘4’ times in the publication of articles on sustainable procurement.

Similarly, for the analysis of the network of institutions using VOSviewer for visualization, the analysis type is set to “organization” and the analysis counting method “fractional counting”. Applied to the analysis, the “minimum number of documents for an organization” was set to ‘2’ and the ‘minimum number of citations of an organization” was also set to ‘5’. Moreover, a network of countries was constructed, utilising countries as the unit of analysis and the "fractional counting" command, the co-authorship analysis was carried out. Additionally, the thresholds for the "minimum number of documents of a country" and "minimum number of citations of a country" were both set to 10.

Journal co-citation networks were developed using Gephi 0.10.1 and VOSviewer software, the analysis type chosen was "co-citation," and the analysis unit chosen was "cited source.". Additionally, 40 was the "minimum citation number source" that was employed. Furthermore, while document co-citation networks focused on important documents, co-citation was chosen, and the analysis technique used was fractional counting. The unit of analysis was "Cited Reference" with a "minimum number of citations" of 10. Finally, an author’s co-citation network was generated using Gephi 0.10.1 and VOSviewer software, co-citation was chosen, and the analysis technique used was fractional counting. "Cited Authors" was chosen as the analytical unit, 40 was the minimum number of citations required.

3. Results and discussions

3.1. Sustainable procurement publication trends

The extracted dataset contains the earliest public document on sustainable procurement, which was prepared by Ref. [26] debated over the use and abuse of environmental labels as they are informing green consumer behaviour. Study findings state that intense industry interest in environmental labels likely arises out of fear that labels will be used as protectionist nontariff trade barriers and, more importantly, that label criteria will be adopted as the basis for government public procurement programs. Berg’s paper titled "Environmental Purchasing Guidelines for organizations" presented at the Air and Waste Management Association’s annual meeting and exhibition outlined the motivations behind environmental purchasing for organizations and with the suggested effective management strategy, focusing on setting goals, allocating resources, auditing, feedback, and response, making reference to the use of such a strategy within the framework of an Environmental Management System (EMS) [27].

Governments frequently favour environmentally superior products in procurement, even if they are more expensive than alternatives, according to Marron’s public budget review opinion from 1997 [28]. In his article, he examines how such green procurement rules affect marginal production costs, how private sector reactions offset changes in government purchasing (crowding out), and how this affects the effectiveness of the regulations. According to Ref. [29] study on environmental sustainability in the provision of affordable housing in South Africa, new building procurement systems show an increasing awareness of sustainability but place more of a focus on economic and social sustainability than environmental sustainability. The paper elaborated on several pertinent principles for sustainable construction, including minimization of resource use; maximisation of resource reuse; maximisation of use of renewable and recycled resources; use of non-toxic materials; protection of nature; achievement of quality criteria; and promotion of sustainable practises. It assessed the degree to which environmental sustainability issues have been incorporated into the delivery of affordable housing in South Africa.

Minerals in Edible Insects by Ref. [30], was one of the most recent articles and provided an assessment of the content and

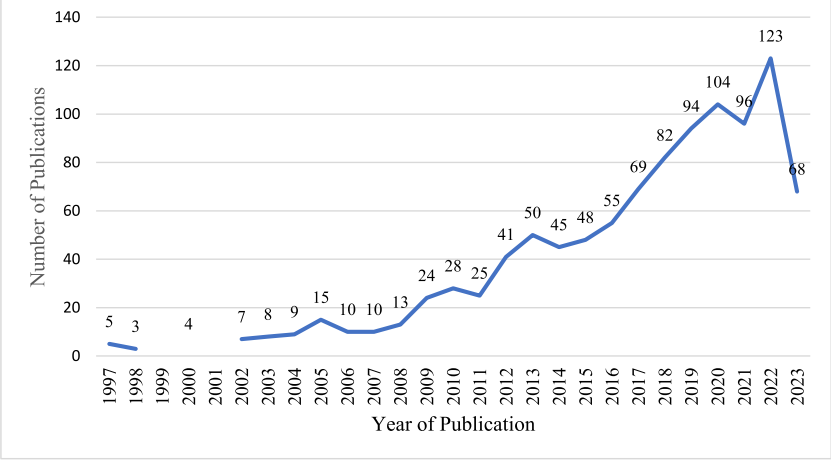

Fig. 1. Literature Publication Trends on sustainable procurement retrieved from Scopus (1997- July 9, 2023).

possibilities for sustainable sourcing for an alternative human food source that is high in proteins, amino acids, and minerals. On the other hand [31], discussed smart agricultural technology within the timber industry. The identification of individual tree logs along the wood procurement chain is a coveted goal within the forest industry, and tracing logs from the sawmill back to the forest would support the legal and sustainable sourcing of wood, as well as increase the resource efficiency and value of harvested timber [31]). With 1044 publications and counting from 1997 to July 9, 2023, including 68 in 2023 thus far, the study of sustainable procurement in all of its varied forms has grown steadily over the years. Fig. 1's steady growth pattern can be attributed to growing concerns about sustainability in the overall procurement process, though not as much as the growth spike that occurred in the last three years (2020–2022), which may have been caused by the COVID-19 pandemic, which necessitated a complete rethink of the procurement process.

The idea that sustainable procurement can provide innovative enterprises with a source of competitive advantage [32] may be one of the main causes for the recent publications examining the barriers to sustainable procurement in emerging economies [33] while employing sustainable procurement strategies in identifying and prioritising challenges and obstacles of supply chain management in various industries [34] When examined closely, sustainable procurement affects all sectors and industries [35]. It has the potential to act as a unifying framework for transdisciplinary research and spur innovation in both academic domains and other industries [36].

3.2. Co-word analysis

A useful strategy for accurately assessing research trends is the formation of keyword networks because of the increased frequency of occurrence in academic articles [37]. According to Ref. [38], an analysis of these keywords gives an idea of the most influential content channels which serve as core elements summarising scientific publication content hence drawing a visual representation of the network of keywords could further shed light on the arrangement and intellectual associations of the various topics covered in this study [39].

Results revealed that the criteria set in the methodology for data processing were met by 29 keywords of the 2509 keywords analysed, which is a 1.2 % inclusion rate. The resultant network hence possessed 29 nodes and 163 links as shown in Fig. 2. Colour scaling was applied to display the average timeline for publications. Keywords such as green procurement, environment, sustainable development, supply chain management and procurement were used in publications between 2016 and 2017. Green supply chain, sustainable construction, public procurement, and lifecycle assessment were predominantly used between 2017 and 2018. From 2018 to 2019, sustainable procurement, sustainable sourcing, and green supply chain management served as major keywords whereas since 2019 till date, new keywords such as construction industry, sustainable supply chain, sustainable public procurement, barriers and circular economy have taken the centre stage.

According to Ref. [40] article, Social Network Analysis, measuring the centrality of nodes is necessary since it is the most accurate way to identify the network's most crucial nodes. By adding the number of linkages between nodes and the total number of nodes in the network, these measures can be made manually [41]. However, this was carried out digitally using Gephi 0.10.1. Network data from VOSviewer was entered into Gephi, which then calculated the network's all-centrality values and retrieved the most significant ones, which are shown in Table 1. The main areas of sustainable procurement studies were ranked based on their relative influence values from the greatest to the least. With the least having the most minute influence in the research area and vice-versa. Table 1 shows the top 15 keywords in the sustainable procurement study over the years. The table ranked based on the betweenness centrality, which reveals any keyword potentially serving as an intellectual driver in sustainable procurement. Keywords were ranked in ascending order.

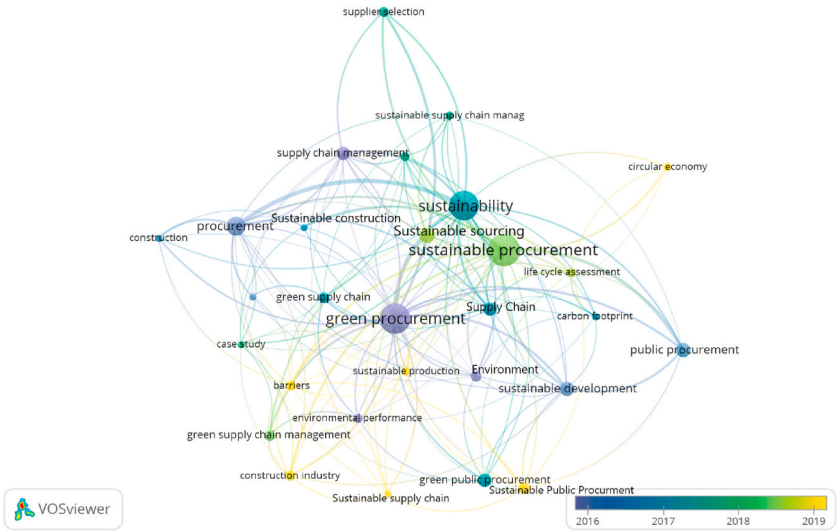

Fig. 2. Main areas of Sustainable Procurement (co-occurrence network of keywords).

Table 1
Relative influence of sustainable procurement keywords.

Keyword	Weighted Degree	Degree Centrality	Relative Influence	First Cited
Green procurement	78.0	24	1	2007
Sustainable procurement	79.0	23	2	1997
Sustainability	90.5	22	3	1997
Procurement	45.0	17	4	1997
Supply chain	27.0	16	5	2000
Supply chain management	25.0	14	6	2000
Barriers	18.0	13	7	1997
Life cycle assessment	13.0	13	8	1997
Green supply chain	13.0	9	9	2005
Sustainable development	28.5	12	10	2002
Environment	13.0	11	11	1997
Construction industry	16.0	11	12	1997
Sustainable sourcing	18.0	12	13	2007
Sustainable production	10.0	12	14	2003
Corporate social responsibility	13.0	10	15	2005

The most extensively studied topics in the study of sustainable procurement are green procurement, sustainable procurement, sustainability, procurement, and supply chain, according to the proportional influence of keywords. It is not a coincidence these keywords are prominent because of their influences on sustainable procurement. The adoption of green procurement strategies into business practises is being driven by the current demand for recyclable products [42], energy-efficient buildings and systems [43], as well as clean fuels and technology [44]. Green procurement refers to the purchase of goods and services that pose the fewest threats and adverse environmental impacts [45]. Green Procurement is the topic of the most research in the field of sustainable procurement because it addresses a variety of issues, such as greenwashing, sustainable supply chain management, life cycle assessment, and carbon footprint [46]. Additionally, the term sustainable procurement supports the objective of organisational sustainability and optimisation of the environmental, social, and economic impacts of the product or service life cycle [47]. The sustainability of cities and communities is the primary goal of sustainable procurement [48], and the research body fully reflects this. When the supply chain is connected to procurement, which is the process of buying goods or services often for commercial purposes [49], it enables people and businesses to be connected and involved in the production and delivery of goods or services [50].

The fields of corporate social responsibility, sustainable production, sustainable sourcing, the building sector, and the environment are those that have received the least attention in the field of sustainable procurement research. The topic of corporate social responsibility is typically only raised during company discussions on sustainable procurement when determining whether stakeholder performance expectations are acceptable. They are there to strategically separate businesses from the competition, increase consumer loyalty, and incorporate ethics into business practices, such as reducing carbon footprints, among other things [51]. More so, sustainable sourcing aligns with sustainable production as the former optimises sustainability for businesses to drive and accelerate targets of sustainability [52]. Furthermore, sustainable production has been gaining traction over the years with a global push for recycling and material reuse, and organizations have since started to look into sustainable productive measures that are less harmful to the environment [53]. The construction industry and environment are the potential "giver and receiver" of decisions on sustainable procurement practices, respectively. Implementing sustainable procurement within the construction industry may result in a more sustainable environment, but failing to do so may also spell constant doom for the environment and result in a failure to meet targets for sustainable development [48]. As a result, there is a need for more research in this field.

3.3. Scientific collaboration networks in CIM: Co-author analysis

It is claimed that the entire aspect of collaboration in scientific studies can be tracked via co-authorship analysis [54] as such, it is essential to understand and properly integrate how researchers communicate with each other. To therefore increase the productivity and efficacy of research, there must be improved access to targeted resources, tools and a large knowledge base on present scientific collaborative networks [55]. Concerning the fact that co-authorships are now a formalised methodological approach of intellectual collaboration among scholars for effective study, collaborations are now becoming adopted on a much larger scale concerning the theoretical and methodological complexity of research [56].

3.3.1. Co-authorship network

Co-authorships are used as tools to study scientific and collaborative patterns and provide a pictorial and network representation of corporative signatures between individuals and organizations in a synchronised format hence broadening the scope of research work and its recommendations [57].

For the co-authorship network analysis of sustainable procurement, Results revealed that of the 2566 authors within the sustainable procurement research space, 33 met the threshold, which is a 1.2 % inclusion rate and were included in the resultant network and visualized using the same software as illustrated in Fig. 3.

A pictorial representation of the co-authorship network is displayed in Fig. 3 with each coloured circle which stands as a node, represents an author and the lines connecting two nodes called the links show relationships between two authors. Using the legend as a

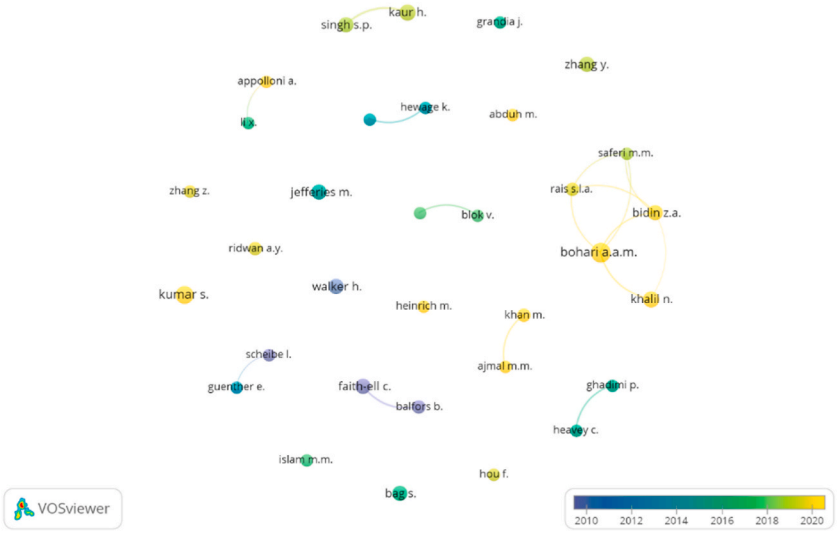

Fig. 3. Key authors in publications on sustainable procurement (co-authorship network).

guide, authors like Scheibe, Faith-ell, Balfors and Walker were predominant co-authors between the periods of 2010–2012. Furthermore, authors like Guenther, Jefferies, Hewage and Ruparathna were predominant between 2012 and 2014. Between the period of 2016–2018, some predominant co-authors were Li, Sjauw-koen, Islam, Bag, Ghadimi and Heavey while from 2018 to 2020 authors such as Bohari, Rais, Zhang, Bidin, Seferi, Ridwan, Kumar and others have taken centre stage.

According to the network, Bohari, Bindin, Khalil, Seferi, and Rais formed the largest collaborative network because they all play a crucial part in the study of green procurement. Their collaborative work on the potential challenges of implementing green procurement revealed solutions for addressing the poor environmental and public health conditions brought on by various construction industries [42]. Additionally, publications by Ref. [58], co-authors of Khalil, highlighted the importance of stakeholder engagement in green construction procurement.

Additionally, Faith-ell and Balfors are key players in sustainable procurement when it comes to the building and upkeep of roads. Their study, which addresses the implementation of environmental requirements, examines the fulfilment and follow-up of the requirements, the client intentions behind the requirements, and the factors that affect the environmental performance of the contractors [58–60]. and additional co-authorships relating to environmental impact assessment, environmental management systems, and green procurement in building projects.

Scheibe and Guenther are significant characters in the investigation of sustainable procurement as a tactic for enhancing value chains. In their study on the use of "hurdles analysis as an instrument for improving environmental value chain management," [61] noted that procurement can be viewed as a significant factor in the goal of greening the value chain and that effective management of procurement processes towards more environmentally friendly procurement can be seen as a good possibility for improving the entire value chain from an environmental point of view. Also applied is the hurdle analysis to the study of green public procurement [62] and as a self-analysis tool for municipalities [63], their most recent work discussed improving sustainable stewardship via the use of Hurdle Analysis [64].

Hewage and Ruparathna's industrial review of the procedure in Canada, which covered methods for making construction practises more sustainable with procurement as a driving force, also stands as a research gem in the field of construction procurement practice [1,65]. As they embrace the usage of big data in their study of sustainable procurement and logistics in the supply chain, Kaur and Singh integrate a more sombre and futuristic approach to their study of sustainable procurement [66]). As evidenced in the following research [67–69], they serve as significant contributors to the literature on enhancing supply chain management using sustainable procurement. In their study on critical success factors for smallholder inclusion in high value-adding supply chains by food & agribusiness multinational enterprises, Sjauw-koen-fa and Blok have also contributed to the use of sustainable procurement in supply chains within the agricultural sector. They discussed sourcing and stabilisation of the supply of agricultural commodities in high-value-adding supply chains, while positively affecting smallholder livelihood [70] and their research [71] on examining the viability of a sustainable smallholder sourcing approach were centred on a black soybean example in Java. The use of sustainable procurement in sustainable manufacturing processes is discussed by Ghadimi and Heavey [72]. More studies demonstrate that the use of sustainable procurement in buyer-seller relationship systems and making sustainable sourcing decisions are of interest to the authors [73,74]. With all these co-authorships established, there is a rich combination of standards and systems that can be fully integrated into every level of industry and commerce.

3.3.2. A network of institutions

Results revealed that amidst 1982 organizations/institutions within the co-authorship space, only 51 organizations met the threshold, which is a 2.5 % inclusion rate. Table 2 was used to rank institutions working on sustainable procurement research areas based on their number of citations and it reveals the top 15 institutions with the University of Southern Denmark, European Business School (EBS) University, business school Germany and Louvain School Of Management, University of Louvain, Belgium standing as the top 3 organizations in the study and possible application of sustainable procurement in various spheres.

Fig. 4 illustrates how the resulting network was further examined and visualized using VOSviewer. Concerning co-citations and co-authorships, this network visualization of institutions showed a collaborative network among institutions. Although there are connections between these institutions, the edges (lines) show that they are tenuous and that there has only been a limited amount of cross-institutional research collaboration. Triangular clustered linkages were formed by institutions such as the College of Civil Engineering and Architecture, Zhejiang University, business school, Zhejiang University and the business school, University of International Business and Economics, Beijing, China. Another was formed by the Department of Entrepreneurship and Relationship Management, University of Southern Denmark, Louvain School of Management and Core, Belgium and EBS business institute for

Table 2
Key Sustainable procurement research institutions based on Documents and Citations.

Organization	Documents	Citations
Department of Entrepreneurship and Relationship Management, University of Southern Denmark, Kolding, Denmark	2	246
EBS University Business School, Institute for Supply Chain Management, Wiesbaden, Germany	2	246
Louvain School Of Management, University of Louvain, Belgium, Belgium	2	246
Enterprise Research Centre, University of Limerick, Limerick, Ireland	3	171
Emmett Interdisciplinary Program in Environment and Resources, Stanford University, Stanford, United States	2	128
Logistics Research Centre, School of Social Sciences, Heriot-Watt University, Edinburgh, United Kingdom	2	119
Natural Capital Project, Woods Institute for The Environment, Stanford University, Stanford, United States	2	75
Business School, University of International Business and Economics, Beijing, China	2	74
Business School, Zhejiang Wanli University, Ningbo, China	2	74
College of Civil Engineering and Architecture, Zhejiang University, Hangzhou, China	2	74
School of Earth and Environment, University of Leeds, Leeds, United Kingdom	3	71
Royal Institute of Technology, Department of Land and Water Resources Engineering, Stockholm, Sweden	3	67
Department for Management of Science and Technology Development, Ton Duc Thang University, Ho Chi Minh City, Vietnam	2	63
Faculty of Social Sciences and Humanities, Ton Duc Thang University, Ho Chi Minh City, Vietnam	2	63
Comsats University Islamabad, Sahiwal Campus, Pakistan	2	53

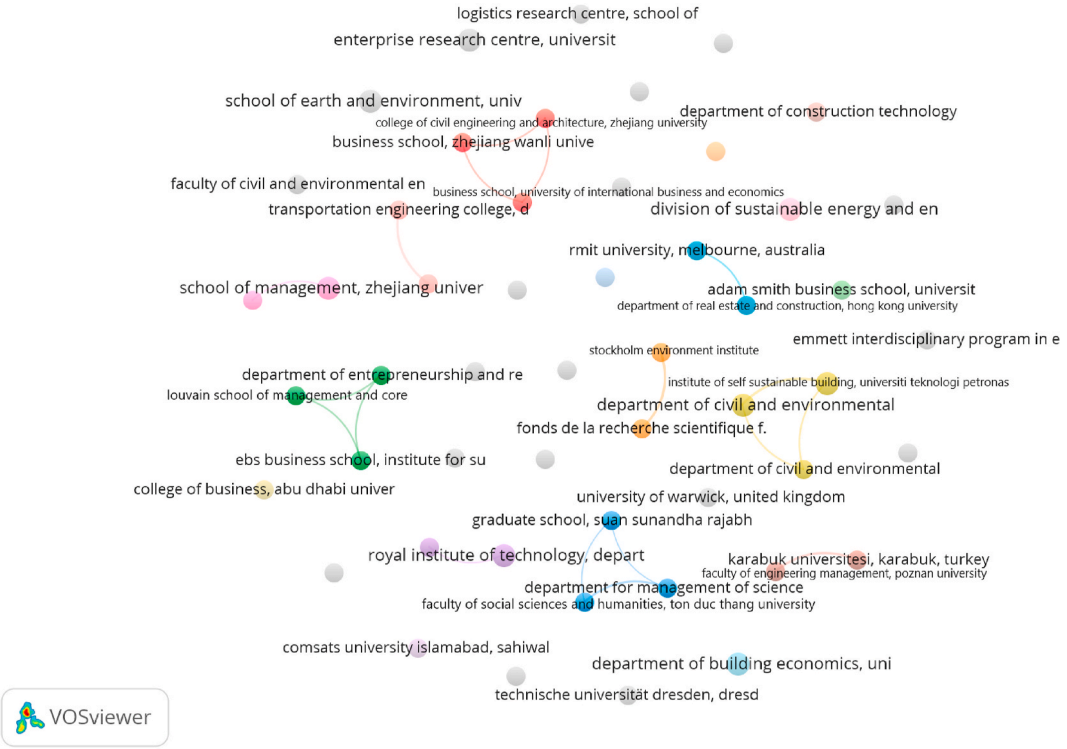

Fig. 4. Sustainable Procurement Citation Network between institutions.

Supply Chain Management, Germany. The graduate school, Suan Sunandha Rajabhat University, Bangkok, Thailand, the Department for Management of Science and Technology Development, Ton Duc Thang University, Vietnam and the Faculty of Social Sciences and Humanities, Ton Duc Thang University, Vietnam. The last was formed by the Institute of self-sustainable building, Universiti Teknologi Petronas, Malaysia and the Department of Civil and Environmental Engineering, Universiti Teknologi Petronas, Malaysia.

A closer look at Fig. 4 reveals that a majority of triangulated clusters are within a particular institution and geographical location suggesting a localization of ideas on sustainable procurement. It can be seen that a majority of institutions found within clusters were either within Asia (China, Malaysia, Vietnam, Thailand) or Europe (Belgium, Denmark, Germany). Drawing an inference from this network, it could be said that there exists a close research relationship between researchers within these geographical locations and ease of access and potential similarities in procurement challenges with regards to region hence the ability to access, co-author and implement research findings. The network visualization also displays linkages between institutions like Fonds De La Recherche Scientifique, Belgium and the Stockholm Environment Institute, Sweden as well as RMIT University, Melbourne, Australia, and the Department of Real Estate and Construction, Hong Kong University showing a dynamic transition in sustainable procurement research cross boarders yet this stands as a minimal fraction when compared to the number of organizations/institutions which met the threshold hence a need for further collaborative effort between more institutions across boards.

3.3.3. A network of countries/regions

The most influential nations within the sustainable procurement sector were determined using a co-authorship analysis to which VOSviewer was applied to recognize the collaborative contribution of nations to the research on sustainable procurement. Results revealed that 34 of the 85 countries discovered satisfied the criteria which is a 40 % inclusion rate and were added to the final network in Fig. 5. The colour grading in Fig. 5 showed the typical publication year. Nations like the United Kingdom, United States, Germany, Sweden, Netherlands, Norway, Thailand, Japan, and Canada under this category, it can be inferred that the bulk of nations began their cooperative efforts to studies on sustainable procurement in 2016 and 2017. In 2018, other nations included Australia, Ireland, China, Brazil, Italy, and Switzerland; more recently, Ghana, India, the United Arab Emirates, Romania, the Russian Federation, and other nations joined the collaboration. Various Nodes (Circles) which were used to depict countries possessed different size variations with the larger more prominent nodes revealing major countries of sustainable procurement research and possible collaborative effort whereas the less prominent nodes and smaller circles reveal areas of lesser research and collaborative effort on sustainable procurement. Also, countries that are closer in proximity within the network have more collaborative efforts than countries that are far apart within the network. It can therefore be deduced that country pairs such as the (US-Netherlands) are more collaborative than (US-India).

Referencing Fig. 5 and the node sizes of these nations, as well as Table 3, it can be said that the United Kingdom and the United States were the most prominent and highest ranked, demonstrating their level of contribution to studies on sustainable procurement. These findings are supported by the facts that the UK's gross spending on public sector procurement alone was £379 billion ($489,359,339,532.8) as of 2021/2022 [75] and $429,580,670,000 for the US [76]. To reduce costs and achieve worldwide goals, it is crucial to handle these enormous procurement numbers properly to ensure spending sustainability and prevent excessive recurrence of expenditure. The fact that countries from different continents of the world are represented in the collaborative space when conducting studies on sustainable procurement is also crucial to note. For instance, the United Kingdom stands to be a central node linking 29 of the 34 countries within the network. The US links to 24 countries whereas, China, South Africa and Germany link 20, 19 and 18 countries respectively. That being said, it is important to note that this form of collaborative effort is healthy within the sustainable procurement research space. There exists quite a reasonable number of comparative studies on sustainable procurement. Furthermore,

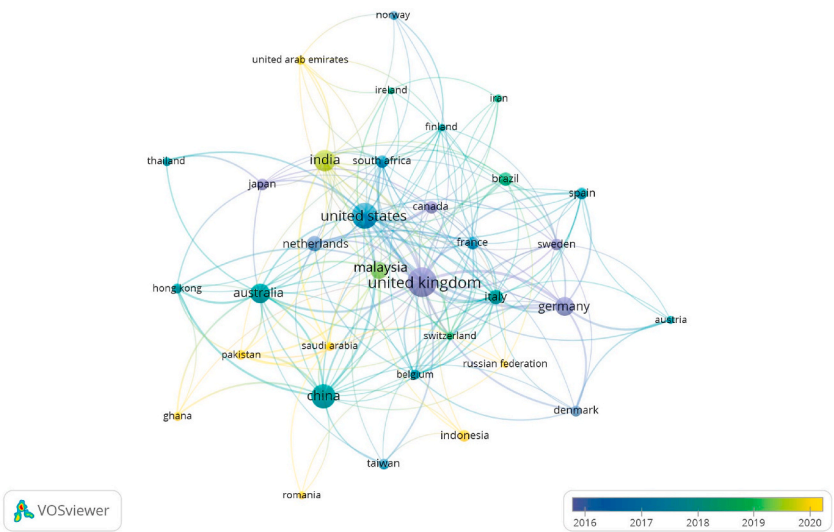

Fig. 5. Main countries of Sustainable procurement research literature.

Table 3
Top 15 countries' collaboration in Sustainable Procurement.

Country	Documents	Citations	Total Link Strength	Percentage (%)
United Kingdom	155	4707	60	19.1
United States	121	2500	46	10.1
China	101	1724	34	7.0
Germany	64	1662	26	6.7
Australia	72	1156	30	4.7
India	81	1124	18	4.6
Netherlands	42	953	14	3.9
Malaysia	53	874	16	3.5
Italy	37	831	25	3.4
France	29	792	16	3.2
Canada	29	758	16	3.1
Sweden	25	636	6	2.6
Taiwan	22	610	5	2.5
Denmark	20	589	8	2.4
Spain	26	571	8	2.3

countries like South Africa and Ghana, reveal that the drive for sustainable procurement is being noticed and interest aroused by scholars in the southern and western parts of the continent.

Focusing on the connections between the various nations in the network, the strongest connections are, in order of importance: The United States and China, Canada and the United Kingdom, Germany and the United States, and the United Kingdom and South Africa. No nation stood alone within the network, demonstrating the diverse range of international cooperation and research on sustainable procurement. Table 3 which rates nations according to their contribution to sustainable procurement research is based on the papers and citations of each country. It is further broken down into percentages of contribution, revealing that the United Kingdom, the United States, and China are major contributors to collaborative works on sustainable procurement, making up 36.9 % of those works with respective contributions of 19.1 %, 10.1 %, and 7 %.

3.4. Co-citation analysis

According to Ref. [77], a co-citation analysis offers a futuristic evaluation of a document's similarity in light of the development of that particular academic subject. When two publications appear in the reference list of another article, they are connected in a co-citation analysis [78]. Consequently, a co-citation of sustainable procurement from the recovered Scopus dataset was examined to let readers receive the best information from a variety of literary publications.

3.4.1. Journal Co-citation networks

Journal co-citation networks are valuable tools in bibliometric analysis, providing insights into the relationships between academic publications by identifying which journals are frequently cited together, thus aiding researchers in discovering key thematic connections and influential sources within a particular field of study.The study used co-citation analysis to collect data from journals that report sustainable procurement from a variety of sources. Results revealed that only 95 of the 20,612 sources matched the requirements which is a 0.5 % inclusion rate and visualized in Fig. 6.

From Fig. 6, the most noticeable nodes represented the most well-known publication sources for research on sustainable procurement, and the weighted degree was utilised to govern the information flow inside and across the network. The use of colours within the network (Red, Blue, Purple, Green and Yellow) were used to highlight the network's most significant clusters and journals. This means that journals within the blue cluster the journal of cleaner production serve as the central outlet. The red cluster has the Journal of Business Ethics, the purple; a Journal of Production Economics, yellow; sustainability and green the International Journal of production economics. Practically visualized were the 95 key sources for sustainable procurement. Having a weighted degree of 934.5, the *Journal of Cleaner Production* emerged as the most significant source for sustainable procurement publication, according to the findings (see Table 4). As a result, Table 4 presents the top 15 most significant sources of information in the research of sustainable procurement, sorted according to their weighted degree in descending order; the degree centrality represents the number of connections a node has to other nodes. This means that there are roughly 73 connections between the Journal of Cleaner Production and different other journals and publications.

The top five most relevant publications for studies on sustainable procurement are the *Journal of Cleaner Production, International Journal of Production Economics, Journal of Business Ethics, Sustainability, and Supply Chain Management*. The publication source Sustainability is the central node that connects all of the clusters (red, blue, purple, yellow, and green) in Fig. 6, making it the most influential source with 90 linkages. This makes it the most linked source of information on sustainable procurement, as the degree of centrality value increases, the more influential the field of study becomes.

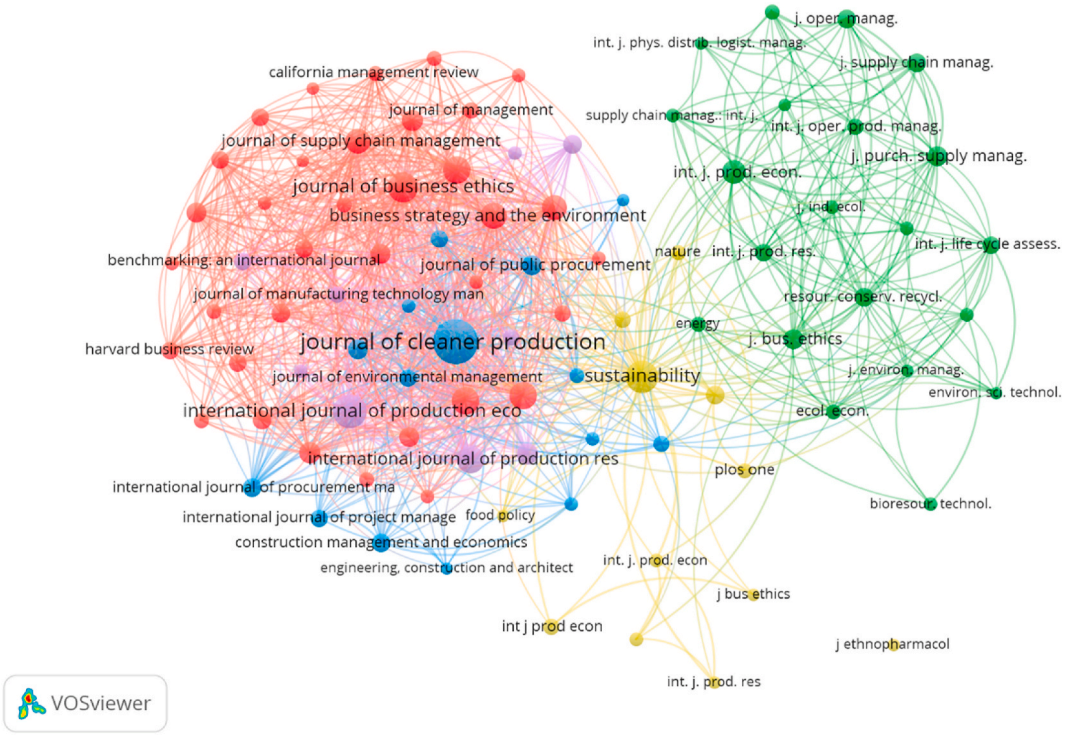

Fig. 6. Network of prominent outlets for publications on Sustainable procurement.

Table 4
Top 15 outlets in the study of sustainable procurement.

Journal	Degree Centrality	Weighted Degree	Relative Influence
Journal of Cleaner Production	73.0	934.5	1
International Journal of production economics	70.0	496.4	2
Journal of Business Ethics	75.0	354.1	3
Sustainability	90.0	327.5	4
Supply chain management: an international journal	77.0	310.9	5
International journal of production research	66.0	291.3	6
Journal of Operations Management	77.0	284.8	7
Journal of purchasing and supply management	77.0	282.1	8
British food journal	77.0	271.9	9
International journal of operations & production management	70.0	246.8	10
Journal of Supply Chain Management	64.0	217.9	11
International Journal of Production Economics	52.0	155.1	12
Academy of Management review	70.0	149.0	13
European journal of operational research	65.0	147.4	14
International journal of operations and production management	67.0	138.8	15

3.4.2. Document Co-citation networks

The document co-citation analysis can be used to examine the intellectual framework of a particular field of knowledge to demonstrate the reliability and importance of the references referenced in publications [79]. There were 48680 cited references among the 1036 retrieved documents, but only 38 of them met the cutoff and only 15 were capture in Table 5 for proper analysis.

Table 5 offers a glimpse into a collection of scholarly articles that have garnered significant attention in the realm of sustainable procurement and related fields. Among these, three articles by Refs. [80,81], and [3] have particularly stood out, each amassing 28, 23, and 18 citations, respectively [3]. work provides an exhaustive examination of sustainable procurement practices, offering a comprehensive analysis of the intricacies involved in integrating sustainability considerations into procurement processes. Their research is instrumental in guiding practitioners and researchers through the complex landscape of sustainable procurement.

[80] study explores the profound impact of sustainable operations on what is commonly referred to as the "triple bottom line." This means they consider not only the economic aspect but also the environmental and social dimensions of sustainability. Their research underscores the critical role that sustainable operations play in achieving a balance between these three pillars, aligning with the core principles of sustainable procurement [81]. undertook an ambitious international comparative study, specifically focusing on sustainable procurement practices within the public sector. Their work provides valuable insights into how different nations approach

Table 5
Top 15 cited articles showing their betweenness centrality.

Reference	Betweenness Centrality	Degree Centrality	Weighted Degree	Citations
[82]. Sustainable supply management: an empirical study	14.5	29.0	32	10
[83]. Green supplier development: analytical evaluation using rough set theory	10.8	16.0	32	10
[84] Firm resources and sustained competitive advantage	9.2	19.0	30	12
[85]. Green Procurement and green supplier development: antecedents and effects on supplier performance	6.9	13.0	29	11
[81]. Sustainable procurement in the public sector: an international comparative study	6.7	16.0	31	28
[86]. The role of purchasing in corporate social responsibility: a structural equation analysis	6.2	13.0	25	17
[87]. A framework of sustainable supply chain management: moving toward new theory.	6.1	14.0	29	17
[80]. Sustainable operations: their impact on the triple bottom line	5.9	10.0	20	18
[88]. Purchasing and supply management sustainability: drivers and barriers.	5.6	9.0	17	10
[89]. A natural-resource-based view of the firm.	5.3	21.0	29	12
[90]. Does sustainable supplier cooperation affect performance? Examining implications for the triple bottom line.	5.3	13.0	27	15
[9]. Special topic forum on sustainable supply chain management: introduction and reflections on the role of purchasing management.	5.0	15.0	29	13
[91] Sustainable procurement in Malaysian organizations: practices, barriers and opportunities.	4.8	13.0	25	11
[3]. Sustainable procurement practice.	4.3	22.0	28	23
[92] Green purchasing practices of our firms	4.0	10.0	26	13

sustainable procurement, highlighting the diversity of strategies and practices employed across regions. This research contributes to our understanding of how governments and public organizations can drive sustainability through their procurement activities.The prominence of these articles in Table 5, as indicated by their high betweenness centrality scores, signifies their pivotal position within the broader academic discourse on sustainable procurement. This suggests that they serve as reference points and intellectual landmarks in the field. As a result, they are crucial resources for both scholars seeking to delve deeper into sustainable procurement and practitioners aiming to implement sustainable practices within their organizations. Overall, these articles underscore the growing importance of sustainability considerations in procurement processes and decision-making, emphasizing the need to balance economic, environmental, and social factors for a more sustainable future.

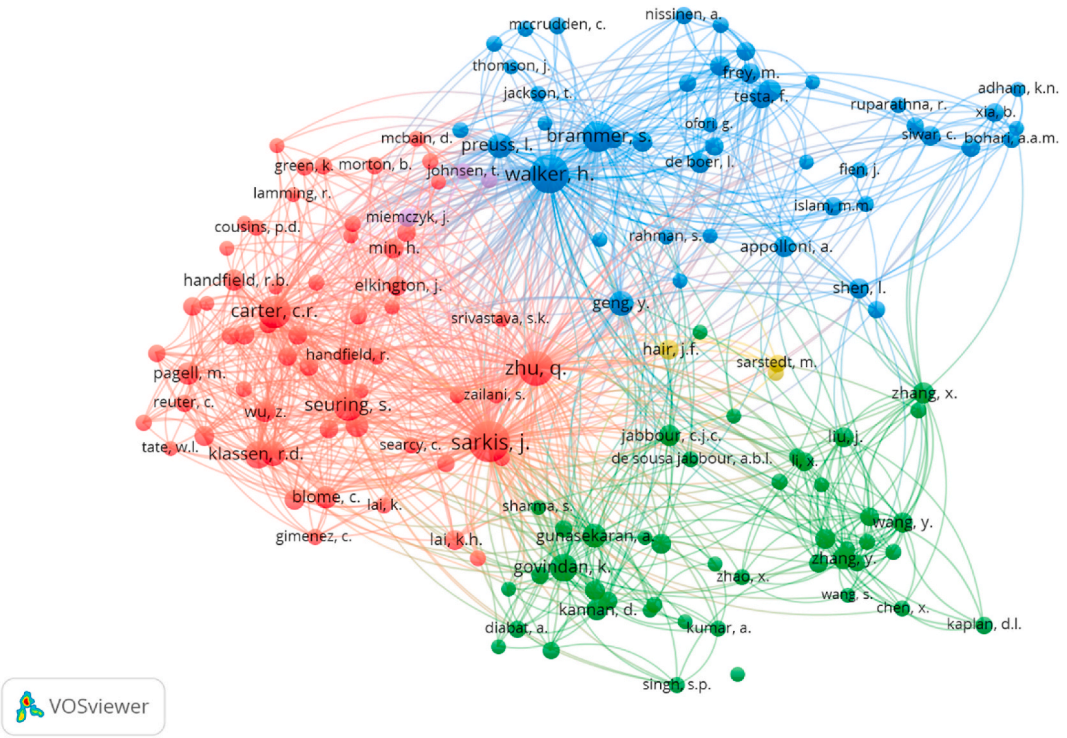

Fig. 7. Authors Co-citation analysis.

3.4.3. Authors Co-citation networks

A study known as an author co-citation analysis is claimed to be able to chart relationships between authors whose works are referenced in the same article and examine the development of research communities [79]. The author's co-citation network is shown in Fig. 7 with 155 nodes and 11,094 links. The 155 authors out of the 55194 writers fulfilled the required 40 minimum number of citations which is a 0.3 % inclusion rate.

The size of nodes links the indirect cooperative ties formed as a result of the frequency of co-citation and indicates the number of co-citations of each author. With 664, 563, 435, 351, 315, 273, 219, 215, 180, and 170 citations, respectively, Sarkis J, Walker H, Zhu Q, Carter C, R, Brammer S, Seuring S, Govindan K, Klassen R D, Preuss L, and Vachon S appear to be the top 10 most co-cited writers. Fig. 7 clearly shows the contributions of these writers, with Walker and Brammer making contributions to the blue cluster and Sarkis Zuh and Carter making the most notable contributions to the red cluster. There are several literature on sustainable procurement, as evidenced by the number of citations.

The next step in the analysis was to look for the betweenness centrality, which reveals the potential intellectual drivers in the area of sustainable procurement. According to the betweenness centrality metrics, the top 10 authors in the study of sustainable procurement are Li Y (Centrality = 13.0), Wang X (Centrality = 12.9), Liu J (Centrality = 12.7), Liu Y (Centrality = 12,7), Chen Y (Centrality = 12.6), Li X (Centrality = 12.4), Sun H (Centrality = 12.4), Li L (Centrality = 12.1), Zhang X (Centrality = 12.0), and Zhang Y (Centrality = 12.0). Despite the possibility that this is the case, it is significant to point out that writers who received a lot of citations did not have a high betweenness centrality. This is quite likely since writers with high citation and betweenness centrality are likely to have a major influence on sustainable procurement. According to the analysis, the three individuals who had the greatest impact on the growth and advancement of the field of sustainable procurement research were Sarkis J (Citation = 664 & Centrality = 7.2), Walker H (Citation = 563 & Centrality = 7.2), and Zhu Q (Citation = 435 & Centrality = 7.2).

The motive behind green public procurement (GPP) in China was examined from an individual-level perspective in one of the collaborative works between Zhu and Sarkis. They claimed that the adoption of GPP practises, particularly in developing nations, is a problem; therefore, to better understand these adoption problems, a conceptual model was constructed that hypothesises the moderating effects of GPP knowledge on the linkages between GPP drivers and practises. Findings reveal that regulations, rewards & incentive gains, and stakeholders exert pressure to motivate the adoption of GPP practices. The knowledge of GPP regulations, responsibilities and experiences in developed countries was also found to be limited [93].

[94] reviewed significant literature on sustainable procurement: past, present, and future, identifying trends in the literature on procurement and supply chain, establishing that this is a developing field, and proposing a sustainable procurement framework to aid in the organisation of future research across supply chains [94]. More specifically, Walker's research included the introduction and procurement fundamentals, which state that a sustainable procurement process offers a way for value to be generated for all parties involved because the prospect of generating value is a powerful motivator for the required level of commitment and enthusiasm needed to produce win-win outcomes as opposed to win-lose ones [95]. Collaboration among authors has been observed in studies like [96] investigation of the connection between sustainable procurement and e-procurement in the public sector and Chen, Zhang X, Yang, Lv, Wu, Lin, Zhang, Wang, Xiao, Zhu, Yu, and Peng's [97]. study on energy evaluation and economic analysis of compound fertilizer production.

4. Conclusion

In conclusion, the scientometric analysis and visualization of sustainable procurement have offered a comprehensive understanding of the field's development, trends, and collaborative efforts. The findings underscore the growing importance of sustainable procurement in addressing global environmental and social challenges, making it a critical area of research and practice for the future. The steady growth in sustainable procurement research over the years reflects an increasing awareness of the urgent need to transition towards eco-friendly and socially responsible procurement practices. The spike in research interest during the last three years, possibly influenced by the COVID-19 pandemic, demonstrates the field's adaptability and responsiveness to external crises. This trend may suggest that the pandemic acted as a catalyst for re-evaluating traditional procurement processes and embracing sustainability-driven strategies, highlighting the field's relevance and resilience.

The co-word analysis revealed key themes that have dominated sustainable procurement research. Green procurement emerged as the most extensively studied topic, emphasizing the importance of sourcing products and services with the least environmental impact. The focus on sustainability, supply chain management, and life cycle assessment further reinforces the multidimensional approach required to achieve sustainable procurement objectives. These themes reflect the interconnectedness of environmental, economic, and social dimensions in procurement decision-making and highlight the need for holistic and integrated approaches.

Collaboration emerged as a vital aspect of sustainable procurement research, as evidenced by the co-author and co-citation analyses. The identification of influential authors and collaborative networks demonstrated the collective efforts of researchers, institutions, and countries in advancing sustainable procurement knowledge. Collaborative partnerships have facilitated knowledge exchange, the dissemination of best practices, and the development of innovative solutions. However, the analysis also revealed regional disparities in collaboration, indicating the potential for enhancing global partnerships and knowledge-sharing across borders.

The significant role of the Journal of Cleaner Production as a central publication outlet underscores the importance of disseminating research findings to a wide audience. As the most influential journal in sustainable procurement, it serves as a hub for sharing cutting-edge research and driving transformative change in procurement practices.

The implications of this research are far-reaching. Policymakers can use the insights to design targeted policies and regulations that promote sustainable procurement in various sectors. Practitioners can draw on the findings to adopt best practices and integrate

sustainable principles into their procurement strategies. Additionally, academics can build on the identified key themes and collaborative networks to advance research and address emerging challenges.

However, despite the progress made, there are still areas of sustainable procurement that require further attention. For instance, the analysis highlighted fields such as corporate social responsibility, sustainable production, and the environment, which received relatively lesser focus in the research space. Addressing these gaps could lead to a more comprehensive understanding of sustainable procurement's broader impact and pave the way for more integrated and inclusive practices.

By offering a comprehensive overview of the sustainable procurement research landscape, this study contributes to evidence-based decision-making and promotes a collaborative approach to advancing a more sustainable and socially responsible world, which is crucial for facilitating sustainability efforts. The significance of this study lies in its potential to provide guidance to policymakers, insights for practitioners, and research directions for academics, thereby enhancing our understanding of sustainable procurement and addressing global sustainability challenges.

Embracing sustainable procurement is not just an academic pursuit but a pressing necessity for creating a more sustainable and thriving world for future generations.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Donatus Ebere Okonta: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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