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GREEN PROCUREMENT TOWARDS SUSTAINABLE DEVELOPMENT IN THE FOURTH INDUSTRIAL REVOLUTION: A BIBLIOMETRIC APPROACH

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Abstract

The use of digital technologies made available by the advent of the Fourth Industrial Revolution (4IR) to respond to contemporary challenges is gaining widespread support across sectors. This article contributes to ongoing discussions on the importance of digital tools by exploring how green procurement contributes to sustainable development. The article (i) identifies research output on green procurement, (ii) explores the leading authors on the topic and the countries they are located in, and (iii) highlights the key recommendations. The article deploys a bibliometric methodological approach covering 27 years from 1997 to 2024. The Scopus database was the source of information, where 133 articles were identified for analysis. The results show that green procurement is widely recommended as among the most effective strategies through which various industries can limit their greenhouse gas footprint and contribute to sustainability. This widespread support and the growth in green procurement research are attributed to the dire need for sustainable development in the 21st century. It is recommended that the industry draw from the results and strengthen its green procurement initiatives.

Keywords: Green Procurement, Fourth Industrial Revolution, Green Supply Chain Management, Sustainable Development Goals, ESG Framework

1. Introduction

The advent of the Fourth Industrial Revolution (4IR) and associated technologies in recent decades has opened up new strategies towards global sustainable development commitments. One of these strategies has been to revolutionise the procurement process. Procurement entails securing goods, services, and works. It is "a multipart process, which includes vendor certification and selection, requisition preparation and approval, order placement, goods receipt, reconciliation and payment of the invoice, and order archiving" (Rejeb et al., 2024, p. 30028). Procurement is the critical function in the supply chain, linking supplier processes to manufacturing and distribution tasks and verifying the quality of inputs (Tan et al., 2021). Conventional procurement focuses on three aspects: quality, cost, and delivery. In addition to these aspects, green procurement adds the need to consider the environmental impacts resulting from social and economic activities (Rane & Thakker, 2020; Sönnichsen & Clement, 2020). Contemporary businesses recognise environmental awareness as an indispensable business imperative, particularly since environmental commitments are now a valuable source of competitive advantage (Rejeb et al., 2024). The importance of these practices has increased the interest in green procurement practices (Mendonça et al., 2021; Qazi & Appolloni, 2022; Zheng & Wen, 2024). This interest has also been supported by the advent of 4IR-based technologies that offer enormous sustainable development opportunities for various social and economic sectors.

The 4IR entails a system of digital-based tools such as computers, sensors, and communication networks connected through the Internet to convey data without being aided by human complexity (Mhlanga & Ndhlovu, 2023). It encompasses the Internet of Things (IoT), artificial intelligence (AI), cyber-physical systems (CPS), virtual

reality (VR), and augmented reality (AR), as well as some mobile technologies, devices, and applications that go together with these systems. These technologies are described as 'smart' (Rushambwa & Ndhlovu, 2023). When functioning in systems, these technologies can control and influence physical procedures and make decentralised resolutions. Using the IoT, CPS can communicate, transfer, and work in partnership with humans in real-time. In the context of procurement, by using the Internet, both internal and cross-organisational activities can be harmonised to boost operational efficiency and effectiveness. Cloud computing is becoming increasingly popular and vital in procurement. Cloud computing is a digital method to add, utilise, and exchange information technology services via the Internet. Some sensors are connected to operate particular programmes and achieve remote Internet control. In procurement, cloud computing and IoT are being used to achieve focused control of machines, equipment, and staff using the Internet. The adoption of 4IR technologies resulted in the emergence of 'smart ' or green procurement.

The concept of green procurement has attracted significant academic interest in recent decades. For instance, based on a systematic review of articles between 1996 and 2013, Appolloni et al. (2014) explored the key themes of green procurement in the private sector. They found that, at the time, the literature on the topic revolved around three themes: the motivations and drivers for implementing green procurement, the barriers to green procurement adoption, and the performance outcomes resulting from green procurement practices. Beer and Lemmer (2011) examined green procurement in food supply chains. They concluded that businesses implementing green procurement and supply chain management practices could help to decrease pollution, improve water quality, and lower greenhouse gas (GHG) emissions. Cheng et al. (2018) assessed the literature related to green public procurement by examining academic texts published between 2000 and 2016. They observed that the literature mainly focused on the specific impact of green public procurement implementations while overlooking discussions on the innovation and efficiency of environmental policy tools. Agyepong and Nhamo (2017) examined climate change and sustainable development and analysed South African legislative provisions for green procurement without a clear discussion on innovation.

Vejaratnam et al. (2020) conducted a systematic literature review to explore barriers to government adoption of green procurement in recent years. The review revealed that a lack of knowledge and awareness was among the significant barriers to government green procurement, while financial constraints represented a minor impediment. Using a literature review strategy, Polonsky et al. (2022) examined potential changes to the procurement process over time. They determined the factors influencing the purchase of products manufactured from recycled or recovered materials. The review showed that public purchasing processes could be improved by adopting green procurement standards, establishing internal organisational support, and sharing information within and with external stakeholders regarding alternative products that contain recycled materials. A literature review of texts involving green and sustainable public procurement published between 2000 and 2020 by Sönnichsen and Clement (2020) flagged a need first to understand the attributes of circular procurement to implement circular public procurement through circular strategy and policy. Sönnichsen and Clement (2020) argue that the procurer's perceptions and values have become more focused on transitioning toward circular procurement. When this happens, the procurement's values shift from merely seeking the lowest price of products to finding the ideal balance of timeliness, risk, and cost based on a product's life cycle. Furthermore, Xu et al. (2022) explored the current condition of circular procurement in private and public sectors by assessing literature published between 1998 and 2021 across three main themes: antecedents, practices, and outcomes.

Although all these works contribute significantly to green procurement discourses, they are either limited in scope, especially the number of papers reviewed, focused on a particular subset of green procurement (for instance, public, private, or industry-specific procurement), or are outdated. Furthermore, very few known studies have broadly deployed bibliometric methods to examine green procurement research in line with sustainable development. Instead, available studies have deployed systematic or conventional literature review approaches and are susceptible to subjectivity, bias, and incompleteness. As a result, there is a knowledge gap regarding the current condition of green procurement, such as identifying the main thematic areas in the literature and the role of digital solutions in green procurement. This has policy and practical implications. This gap can be addressed by using bibliometric methods.

Furthermore, previous studies have not applied co-citation analysis, which can assist in unearthing the green procurement literature's history, basis, and intellectual structure. Therefore, a comprehensive and in-depth bibliometric analysis is vital to provide novel insights and advance the topic. Unlike conventional reviews, which may be labour-intensive, biased, and inefficient for the examination of larger literature bodies, bibliometric analyses allow researchers to organise, synthesise, and quantitatively assess the evolution of a topic using a large number of publications (Rejeb et al., 2024). Because the bibliometric approach is data-driven and involves a wide variety of textual materials (Ndhlovu & Dube, 2024), it wields much potential for an unbiased and impartial analysis

of a scholarly area. To the best of our knowledge, no previous studies have sought to broadly analyse the knowledge structure of green procurement research as a pathway towards sustainable development in the era of 4IR. This article seeks to close this literature and knowledge gap. The article (i) identifies research output on green procurement, (ii) explores the leading authors on the topic and the countries they are located in, and (iii) performs a content analysis of the key terms of the identified texts.

The article proceeds as follows: After the introduction, the next section discusses the link between green procurement and sustainable development. An outline of the research methodology for the article follows this. After that, the results are presented and discussed concurrently. The article then presents future research and policy directions. Lastly, conclusions are drawn from the results and the discussion.

2. Green Procurement and Sustainable Development

The concept of 'green procurement' is often used interchangeably with terms such as 'sustainable procurement', 'eco procurement ', and 'environmentally responsible procurement' (Rejeb et al., 2024). Green procurement denotes the efforts by organisations to reduce, reuse, and recycle materials in their operations. It is an ecologically mindful purchasing initiative aiming to meet the company's eco-friendly goals. (Chersan et al., 2020; David & Muthini, 2019). Green procurement also refers to the selection of suppliers, the buyers of environmentally-friendly goods and services, and the prioritisation of environmental conditions in operations. Green procurement is also defined as purchasing items and services with lower environmental impacts (David & Muthini, 2019). For Chersan et al. (2020), green procurement refers to buying items or services with a lower environmental effect across their entire life cycle than their regular counterparts. It is also the process of integrating environmental commitments into purchasing decisions that are made based on performance, quality, and price concerns (Wang & Zhang, 2024). According to Asif et al. (2020), green procurement is essentially the principle of averting pollution to eradicate or reduce human health and environmental risks. Green purchasing entails the evaluation of purchases based on several principles ranging from purchase necessity to availability of eventual disposal options (Jum'a et al., 2022). The sustainability concept is at the centre of green procurement. Whatever green procurement efforts businesses make; the aim is to satisfy their sustainability commitments. Sustainable procurement supports an organisation's sustainability commitment and optimises the environmental, social, and economic impacts over the life cycle of the product or service (Arora et al., 2020).

Green procurement has been observed to wield much potential regarding reducing carbon emissions (Asif et al., 2020; Gong et al., 2019). Deshpande et al. (2020) mention that green techniques include eco-labelling, working with suppliers to meet environmental goals, conducting environmental audits, designing for recycling and reuse, and minimising the use of hazardous materials. Bozdogan et al. (2021) found that using energy-efficient methods can significantly help lower business expenses by reducing HVAC systems, refrigerators, and cool fluorescent lamps. Ilyas et al. (2020) also argue that sustainable sourcing needs to be recognised as a vital component of strategic sourcing and as a cost-cutting technique that adds value, improves firm economics, protects the environment, and improves customer impression of the brand. Furthermore, green procurement can also result in costs and energy efficiency (Huang et al., 2024).

According to Ciumara and Lupu (2020), enterprises that engage in green procurement characteristically emphasise the need for balance between quality, pricing, delivery, and environmental considerations. Green procurement wields much sustainability potential because it does not involve a single actor from the economy but the whole supply chain. Besides, it applies to both public and private entities. For this reason, it is widely considered a vital sustainable development tool (Jum'a et al., 2022; Shen et al., 2017). While companies use other important tools, such as integrated reporting and environmental management accounting, green procurement's sustainability characteristics make it the most popular and preferable.

The environmental problems characterising the contemporary era do not have a precedent and are so severe that they require immediate action and intervention from all the actors involved. For this reason, governments worldwide now appreciate the benefits of green procurement methods, such as cost savings from decreased energy use, resource use, and material management (Huang et al., 2024). Many governments from the European Union, the United States of America, and South Africa are adopting some environmental policy instruments that are aimed at inspiring or even imposing green behaviour on both businesses and consumers (Florek-Paszkowska & Hoyos-Vallejo, 2023; Rejeb et al., 2024; Wang & Zhang, 2024).

Individual businesses worldwide have also been making efforts in recent decades to improve their operations and product environmental performance in line with green procurement practices. This green procurement practice is evident for specific products such as content-recycled office paper, paints, cleaners, renewable energy, and the materials, substances, and chemicals purchased for products and services provided (Likholo & Senelwa, 2022). In recent years, most enterprises have also been developing green procurement policies and rules covering

a wider products and services and environmental issues (Singh et al., 2024). The primary driver of green purchasing, therefore, is environmental preservation. Waste management is considered a cost-cutting method businesses may use to maintain their competitiveness in the global market (Sönnichsen & Clement, 2020).

The practice of green procurement is, however, still evolving. As a result, it is still facing several challenges. Companies often find it hard to change organisational strategies (Arora et al., 2020). Businesses also often lack adequate knowledge for green procurement implementation (Bozdogan et al., 2021). Some organisations lack knowledge on applying sustainability procedures and, specifically, adopting green procurement procedures (Bozdogan et al., 2021). Organisations often experience political, economic, social, and environmental issues.

Regarding political challenges, the governments of countries (local and national) play an important role in promoting sustainability in businesses. Governments often use legislation and regulations to force businesses to operate sustainably. Several studies have shown that government-assigned regulations and legislation are crucial to green procurement in enterprises (Likholo & Senelwa, 2022; Salleh et al., 2023; Vejaratnam et al., 2020). However, in most developing countries, the absence of legislative mandates or incentives significantly impairs sustainable practices (Chersan et al., 2020).

Environmental challenges also impede sustainability practices. Deshpande et al. (2020) argue that the lack of stakeholder understanding is one of the main challenges in implementing green procurement. Many practitioners lack adequate knowledge or experience in green procurement or its significance (Florek-Paszkowska & Hoyos-Vallejo, 2023). Most enterprise managers tend to lack knowledge of how sustainability issues can be integrated into the procurement process (Rane & Thakker, 2020). It is also argued that many organisations still lack skilled employees who can handle green procurement (Buniamin et al., 2016).

Economic limitations also present enormous challenges to the achievement of sustainability practices. Cost challenges are a significant factor in companies' implementation of green procurement. Some scholars have pointed out that sustainability activities and operations are costly for businesses (Ciumara & Lupu, 2020; Florek-Paszkowska & Hoyos-Vallejo, 2023).

Lastly, social factors also impede the successful pursuit of sustainable practices. Djokoto et al. (2014) found that resistance to change was a significant obstacle to green procurement in Ghana. These scholars found that many people found it hard to change their thinking in the construction sector, especially regarding the traditional construction techniques and equipment used in the industry. The success of sustainability practices requires the support of management. The lack of commitment by managers, therefore, can hamper the implementation of green procurement. In addition, scholars have limited interest in tackling how green procurement can help address sustainability issues. In this view, this study seeks to fill this gap by showing where, how, and how green procurement has been studied using bibliometric analysis.

3. Method

This study on green procurement towards sustainable development in the fourth industrial revolution is underpinned by a bibliometric methodological approach. It is crucial to underscore that bibliometric analysis is gaining popularity as a comprehensive method of interrogating existing literature in order to unpack the research agenda (Bhandari, 2023; Cheng et al., 2023; Florek-Paszkowska & Hoyos-Vallejo, 2023; Mhlanga & Dzingirai, 2024; Salleh et al., 2023). This study applied the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach to cement the methodological rigour and foster the credibility of the results. The PRISMA for this study is depicted in Figure 1 as a methodological flowchart.

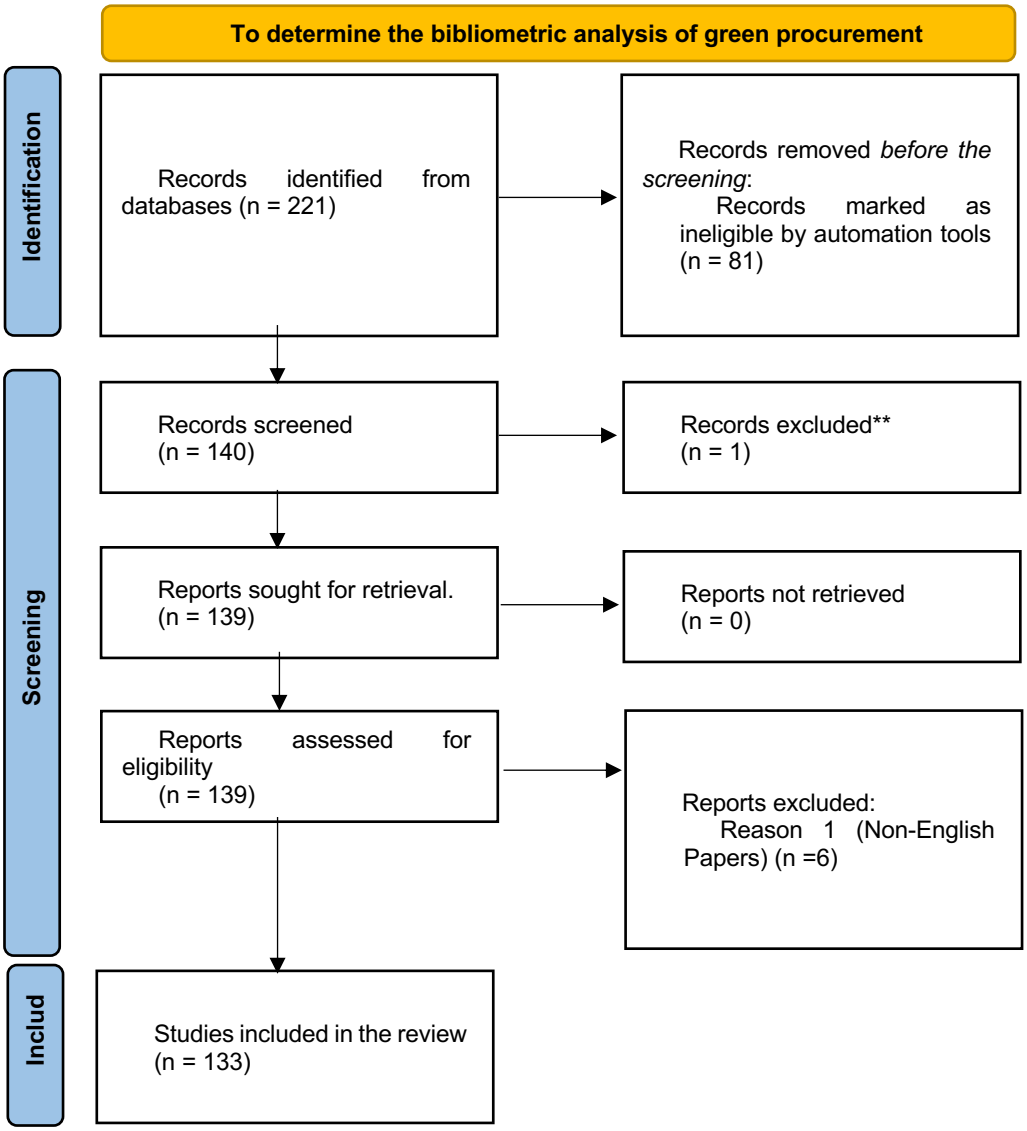

Figure 1. Methodological flowchart

It is worth noting that data exploration and planning play a significant role in bibliometric analysis, which is associated with robust literature reviews. In this respect, four stages of data exploration and planning were considered to be of utmost importance in this study: acquisition of data, pre-processing of data, statistical computation, and application analysis. The search strategy is central to methodological rigour and trustworthiness in bibliometric analysis. In this sense, green procurement was used as the search strategy in the Scopus database. The Scopus database is widely used for credible scientific inquiry (Ejaz et al., 2022; Pradini et al., 2023; Rahman et al., 2023). The literature search in the Scopus database was done on 5 September 2024. The first search generated 221 documents, and then 65 conference papers, 10 reviews, five book chapters, 1 book, 1 short survey, and 6 non-English papers were excluded. In this regard, the final sample size was 133 documents (articles only). The VOSviewer 1.6.20 was employed as the data analysis software to analyse the bibliometric data related to green procurement.

4. Findings and Discussion

This section presents the bibliometric results and discusses the scientific mapping of green procurement. It was most appropriate to examine the research productivity related to green procurement, and the results are presented as follows:

4.1. Trajectory of Outputs

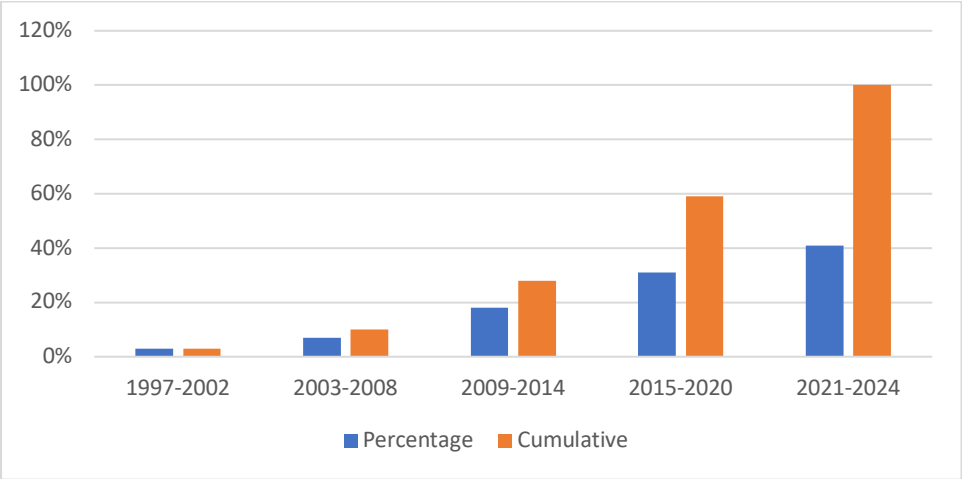

Figure 2: Research Output on Green Procurement

As illustrated in Figure 2, there has been an exponential increase in research output from 1997 to 2024, which is substantiated by the fact that green procurement is a trending concept in the current sustainable development discourse. Many scholars suggested that green procurement is at the heart of sustainable development and circular economy (Mungkung et al., 2021; Singh et al., 2024; Zheng & Wen, 2024). As revealed in Figure 2, 3% (4/133) of the total documents were published from 1997 to 2002. This indicates that the first article on green procurement was published in 1997. Notably, 7% (9/133) of the total publications were published from 2003 to 2008, and then 18% (25/133) were published from 2009 to 2014. A total of 41 articles were produced from 2015 to 2020, which accounts for 31% of the total. More interestingly, 41 articles were published from 2021 to 2024, which is 41% of the total article publications. In terms of trend analysis from 1997 to 2024, there was a 1266.67% increase in research output when it comes to green procurement. This may be linked to the fact that many scholars, researchers, policymakers, and practitioners are advocating for green procurement as a strategic move towards attaining the African Agenda 2063 and the United Nations' Sustainable Development Goals.

4.2. Prolific countries

With robust statistical analysis of countries' performance in green procurement, it was deemed most appropriate to report the most prolific countries, focusing on the top 10 performing countries. The results from the VOSviewer software are reported as follows:

Top 10 most prolific countries

In the context of sustainable development, it is most appropriate to examine the most prolific countries with respect to green procurement. To effectively examine the top 10 most productive countries, the researchers used a minimum count of 2 documents for inclusion and also a minimum threshold of 2 citations. Given that 30 countries met the inclusion criteria out of 54 countries, the total link strengths of the qualified 30 countries were computed, and the research outcomes are summarised in Table 1.

Table 1: Top 10 most prolific countries

Countries	Documents	Citations	Total link strength
China	32	1120	22
Canada	5	51	10
UK	9	834	10
Australia	7	233	9
Saudi Arabia	4	66	7
Ghana	6	69	6
India	12	275	6
Italy	5	224	6
Malaysia	10	160	5
Iran	2	22	4

As reported in Table 1, China is the most productive country in terms of green procurement, as evidenced by 32 published articles. This can be attributed to the fact that China is supporting the adoption of sustainable business practices, green investment, green supply chains, and eco-innovation (Huang et al., 2024; Shen et al., 2017; Wang & Zhang, 2024). More interestingly, as one of the African countries, Ghana is also on the top 10 most productive list, as revealed in Table 1. Furthermore, the visualisation of all the 30 qualified countries is captured in the following Figure 3:

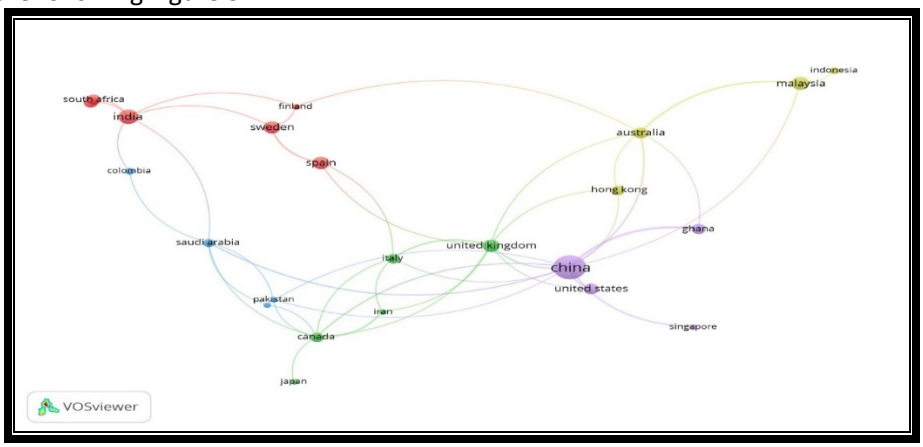

Figure 3: Bibliometric coupling of countries

Figure 3 illustrates that China and India have 32 and 12 documents, as the big circles indicate. This suggests that developing countries are pushing for a green revolution, sustainable business practices, and eco-innovation.

4.3. Bibliometric coupling of organisations

Within the context of bibliometric coupling of organisations, organisations that had a minimum of 2 documents were considered in this in-depth analysis. A total of 279 authors were generated, and then only 5 organisations met the inclusion criteria, as shown in Table 2 below.

Table 2: Most productive organisations

Organisation	Documents	Citations	Total link strength
China Academy of Launch Vehicle Technology, China	3	69	3
Royal Institute of Technology, Sweden	4	8	3
University of Cape Coast, Ghana	4	83	3
University of Electronic Science and Technology of China, China	2	74	1
Dalian Maritime University, China	2	4	0

4.4. Most productive authors

In terms of the assessment of prolific authors within the context of green procurement, a minimum of 2 documents was used. Out of 360 authors, only 32 met the inclusion criteria. To effectively assess and arrange prolific authors according to total link strengths, there was a dire need to capture the top 10 most prolific authors with respect to green procurement, as reported in Table 3.

Table 3: Top 10 prolific authors

Authors	Documents	Citations	Total link strength
Bohari, asmah alia Mohamad	6	138	15
Khali, Natasha	5	64	12
Xia, Bo	3	135	10
Skitmore, Martin	2	135	7
Teo, Melissa	2	135	7

Acquah, Innocent Senyo Kwasi	2	61	6
Afum, Ebenezer	2	61	6
Agyabeng-Mensah, Yaw	2	61	6
Baah, Charles	2	61	6
Balfors, Berit	4	269	6

4.4. Content Analysis of Co-occurrence of Keywords

Content analysis of the co-occurrence of keywords is vital in bibliometric analysis as it can help researchers map further research directions. Interestingly, co-occurrences of keywords can be deemed beneficial as they assist researchers in scientifically picking the trending research themes and emerging research themes in the area of inquiry (Cheng et al., 2023; Wu & Chow, 2024). Keeping this in mind, the researchers conducted the content analysis of the co-occurrences of keywords related to green procurement, and the results are presented in Figure 4.

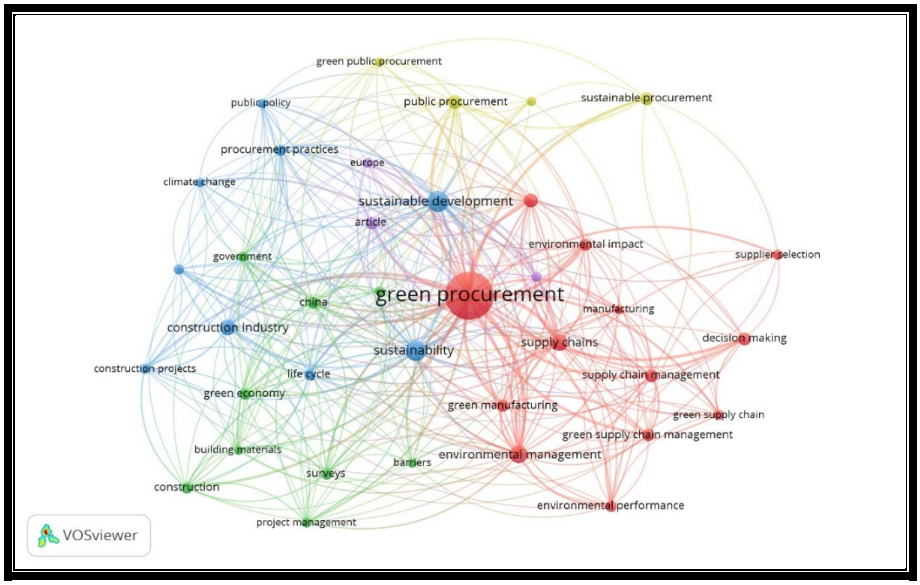

Figure 4: Content Analysis of Keywords

As shown in Figure 4, the colour of the nodes depicts the cluster category. According to Wu and Chow (2024), cluster analysis refers to deciphering large datasets in performing bibliometric analysis. In this study on green procurement, 5 clusters were observed from the bibliometric data. The first cluster constituted 13 keywords: decision-making, environmental impact, environmental management, environmental performance, environmental protection, green manufacturing, green procurement, green supply chain, green supply chain management, manufacturing, supplier selection, and supply chains. The second cluster had 9 keywords: barriers, building materials, China, construction, environmental economics, government, green economy, project management, and surveys. The third cluster encompassed 9 items: climate change, construction industry, construction projects, greenhouse gases, life cycle, procurement practices, public policy, sustainability, and sustainable development. The fourth cluster had four keywords: circular economy, green public procurement, public procurement, and sustainable procurement. Lastly, the fifth cluster consisted of 3 keywords: article, Europe, and sales.

As presented in Figure 4, there are some key trending themes on green procurement (133 co-occurrence times), sustainability development (26 times), sustainability (24 times), environmental management (18 times), and supply chains (16 times). This implies that green procurement is gaining momentum owing to the clarion and urgent calls for sustainable development at a time when the Africa Agenda 2063 and Sustainable Development Goals are gaining traction in the literature. Put simply, green procurement and sustainable development work hand in hand. To broaden our understanding of the trending theme in green procurement, a total strength analysis was performed to determine the top 10 trending themes, as presented below.

Table 5: Top 10 trending research areas

Keyword	**Occurrences**	**Total link strength**
Green procurement	133	328
Sustainable development	26	112
Sustainability	24	101

Environmental management	18	94
Supply chains	16	78
Construction industry	14	56
Article	10	55
China	9	49
Environmental protection	11	48
Public procurement	12	45

Table 5 reveals that green procurement is mainly attributed to sustainable development, whereby scholars, researchers, and practitioners advocate for environmentally friendly business practices. In this sense, green procurement cannot be underestimated in the public and private sectors. This is why China is putting green procurement on the sustainable development agenda in the quest to reduce the emission of greenhouse gases.

5. Further Research Areas

Following a thorough bibliometric analysis of green procurement, scientific research gaps were exposed, which can be a pointer for future research directions. These scientific gaps and future research directions are reported in the following table.

Table 6: Research agenda

Literature gaps	**Research directions**
Green procurement is underexplored in the Southern African Development Community (SADC) region.	Scientific studies on green procurement focus on the SADC region, especially on sustainable supply chains and green procurement practices.
The linkage between green procurement and sustainable development goals.	Empirical studies focus on how green procurement can accelerate achieving sustainable development goals.
Little is known about green public procurement in Sub-Saharan Africa.	Research on the benefits and challenges of green public procurement in Sub-Saharan Africa.
Linkage between green procurement and green manufacturing.	Analysis of the connection between green procurement and green manufacturing.
Comparative analysis of green procurement in both developed and developing countries.	Investigate the contextual factors influencing the adoption of green procurement among countries.
Cluster analysis of green procurement.	Research on statistical cluster analysis of keyword occurrences related to green procurement.

6. Theoretical, Policy, and Practical Implications of the Study

This study on green procurement towards sustainable development introduced a unique bibliometric approach to green procurement research. To the authors' best knowledge, this study is the first of its kind to introduce bibliometric analysis of the linkage between green procurement and sustainable development. Practitioners and business professionals can use the bibliometric results to design the terms of reference related to green procurement. Moreover, they can also employ international best practices concerning green procurement. Policymakers should adopt the results when designing strategic plans and devising green procurement policies. More interestingly, governments across the globe can also come up with green procurement regulatory and supervisory frameworks for sustainable development.

7. Conclusions

This bibliometric study on green procurement demonstrates how green procurement can be utilised to ensure sustainable development. The period covered in this research ranges from 1997 to 2024, using bibliometric data from the Scopus database. The bibliographic coupling of authors, organisations, and countries was done. More interestingly, content analysis of co-occurrences of all keywords was done to expose notable literature gaps for further research. The results revealed that green procurement research has grown exponentially from 1997 to 2024. The research outcomes of this bibliometric have substantial implications for practice, theory, and policymaking. This suggests that the growth in green procurement research has been attributed to the dire need for sustainable development in the 21st century. Accordingly, it is deemed necessary to conclude that green procurement is a trending concept that is opening new research areas.

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