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Emerging Technologies Revolutionising Public Procurement: Insights from Comprehensive Bibliometric Analysis

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Abstract: This study aims to deepen our understanding of the evolving landscape of public procurement (PP) and emerging technologies (ET). It addresses the critical gap in scholarly production analysis, author collaborations, and thematic trends in PP and ET, providing valuable insights for researchers, policymakers, and practitioners. Employing a methodology inspired by prior research, this study leveraged advanced bibliometric tools, including Studio R and the Biblioshiny app, for data retrieval, processing, and visualization. This approach facilitated co-citation, source coupling, and network collaboration analyses. Thematic maps and correspondence analysis were used to explore research themes in depth. The findings highlight a significant surge in research interest in the integration of ET in PP since 2018, underlining the growing importance of technology-driven advancements in the field. These insights are vital for shaping policy decisions, spurring innovation, and enhancing PP processes' efficiency, transparency, and sustainability, which are crucial for effective governance and economic growth.

Keywords: bibliometric analysis; co-citation networks; correspondence analysis; emerging technologies; public procurement; thematic map

1. Introduction

Public procurement is the process by which governments and public organisations acquire goods, services, and works, playing a crucial role in the efficient operation of societies worldwide (OECD 2019; Siyal and Xin 2020; Bovis 2020; Ambe 2019; Bertocchi et al. 2022). The decisions made in PP have far-reaching implications, affecting areas as diverse as infrastructure development, healthcare delivery, education services, and national defence. Therefore, it is essential for governments and public organisations to continually evolve and improve their procurement practices to ensure transparency, efficiency, and sustainability (Hochstetter et al. 2023). In recent years, the landscape of PP has witnessed a profound transformation driven by the integration of ET, commonly referred to as Industry 4.0 or the fourth industrial revolution (Garay-Rondero et al. 2020; Gottge et al. 2020; Weking et al. 2020; Schiele et al. 2021; Horváth and Szabó 2019; Mavidis and Folinas 2022).

Emerging technologies (ET) are at the forefront of driving innovation and change across various sectors (Niebel et al. 2019). While they offer significant benefits, they pose challenges and require careful consideration regarding governance, policy-making, and societal impact. ET encompasses many innovations, including but not limited to artificial intelligence (AI), blockchain, big data analytics, Internet of Things (IoT), 3D printing, and machine learning. These technologies are revolutionising how PP processes are conducted, monitored, and optimized (Deloitte and European Commission 2020; Triana Casallas et al. 2020; Cui 2018; Modrušan et al. 2021; Ubaldi et al. 2019). Emerging

technologies like the combination of the Internet of Things (IoT) and blockchain, termed Blockchain and Internet of Things (BIoT), lead to smarter, more sustainable, and transparent public procurement processes (Mircea et al. 2022).

This comprehensive bibliometric analysis sheds light on the evolving intersection between PP and ET. It seeks to explore the extent to which these technologies have penetrated the field of PP, their impact on procurement practices, and the collaborative networks and thematic trends that have emerged as a result. The significance of this analysis lies in its ability to provide a holistic understanding of the evolving dynamics within the domain of PP. By employing bibliometric techniques, we can uncover hidden patterns, identify key research themes, and recognise the influential voices shaping this field. Such insights are invaluable for researchers, policymakers, practitioners, and stakeholders invested in the future of PP. The primary objectives of this study are as follows: (1) To assess the scholarly production trends in public procurement and emerging technologies over the past two decades, highlighting the growth of research output and its implications. (2) To identify the most influential journals and authors contributing to the discourse on public procurement and emerging technologies, recognising the key players in this evolving field. (3) To analyse the collaborative networks among authors, institutions, and countries, revealing the dynamics of knowledge exchange and interdisciplinary collaboration. (4) To uncover the thematic landscape of research in this area, identifying key themes, emerging trends, and their interconnections. This study draws inspiration from prior research, particularly the methodology outlined by Rejeb et al. in 2023, which serves as a guiding framework for our analysis. Leveraging advanced bibliometric software and databases, including Scopus and Web of Science, we conduct a comprehensive examination of PP research with a focus on the integration of ET. Our methodology encompasses data collection, processing, and visualisation, enabled by tools such as Studio R and the Bibliometrix package. The Scopus database and Bibliometrix package were used in a comprehensive bibliometric analysis to uncover the evolution of technology-driven procurement practices (PP). A structured search query retrieved articles encompassing emerging technology keywords and the phrase "PP". Network analysis techniques, such as collaboration networks and thematic mapping, were employed to uncover intricate relationships among authors and research themes.

The research employs a multifaceted bibliometric analysis to explore the integration of emerging technologies (ET) in public procurement (PP), utilizing thematic analysis, correspondence maps, collaboration network analysis, scholarly production and prominent authors review, co-citation network, and clusters by sources coupling. The collaboration network analysis highlights the importance of global partnerships and collaborative efforts in PP and ET. Analysis of scholarly production and prominent authors sheds light on key contributors and thought leaders, guiding future research directions. The co-citation network offers insights into the intellectual lineage and influential publications in the field, while clusters by sources coupling reveal thematic groupings and research concentrations. Key achievements of this study include the emphasis on interdisciplinary collaboration and cross-sector partnerships essential for advancing PP. It identifies the need for data-driven approaches in supplier selection and underscores the transformative potential of blockchain for transparency and security in PP processes.

Additionally, emerging trends in big data, data handling, and cluster analysis are identified, suggesting the development of new methodologies for effective data management in PP. Integrating blockchain architecture and open data in procurement procedures is also a significant finding, indicating innovative PP research and practice approaches. This comprehensive analysis provides actionable insights for researchers, policymakers, and practitioners, charting a course for future explorations in the dynamically evolving domain of PP and ET.

2. Materials and Methods

2.1. Research Objectives and Questions

In bibliometric analysis, the fundamental procedure is to set up the objectives and the research questions. Then, we have to choose the proper techniques and, in the following steps, collect the data and run the analysis with the proper tools.

Objective 1: Evaluate the historical development of scholarly production in PP and ET. Evaluation includes quantifying the annual scientific output, identifying turning points in research interest, and forecasting future growth trends.

RQ 1.1: What is the historical trend in scholarly production at the intersection of PP and ET?

RQ 1.2: Are there any significant turning points or inflexion years in the number of papers published in this field?

Objective 2: Identify and rank the most influential journals in this interdisciplinary field. This ranking is based on citation frequencies and assists as a guide for researchers to select reputable sources for their literature reviews and studies.

RQ 2.1: Which journals have received the most citations in public procurement and emerging technologies?

RQ 2.2: How can we rank these journals based on citation frequency, and what does this ranking reveal about their influence?

Objective 3: Analyse prominent authors in the context of PP and ET to provide a deeper understanding of the intellectual leaders in the field, their contributions, and their collaborative networks.

RQ 3.1: Who are the prominent authors in the field of PP and ET, and what are their publication relevance?

RQ 3.2: Are there any collaborative patterns or networks among these influential authors?

Objective 4: Examine the collaborative relationships, co-authorship networks, and knowledge-sharing dynamics, shedding light on subfields and research groups within the subject.

RQ 4.1: Can we identify clusters or communities of authors who frequently collaborate, and what do these clusters signify?

Objective 5: Map the key thematic clusters and explore relationships between ET, procurement procedures, and their implications.

RQ 5.1: What is the conceptual structure of research in PP and ET, and how can it be represented through thematic maps?

RQ 5.2: Which thematic clusters emerge from the analysis, and what are their key characteristics and relationships?

Our objectives and research questions align with the goals of a comprehensive bibliometric analysis in PP and ET. They are structured to provide a thorough understanding of the scholarly landscape, key contributors, and the thematic and collaborative dynamics within the interdisciplinary field.

2.2. Method

The methodology in Figure 1 for this study drew on prior research conducted by Rejeb et al. in 2023, which served as a guiding methodology map (Rejeb et al. 2023). Additionally, this study leveraged the advancements in bibliometric software and the accessibility of scientific databases, such as Scopus and Web of Science, to comprehensively analyse PP research. The increasing development, accessibility, and availability of advanced bibliometric software tools, including Gephi, Leximancer, Studio R, Biblioshiny, and VOSviewer, have played a pivotal role in the popularity of bibliometric analysis (Donthu et al. 2021). These tools provided robust data retrieval, processing, analysis, and visualisation capabilities. In this study, we utilised Studio R along with the Bibliometrix package, which offers a wide range of functions to handle bibliographic data effectively (Aria and Cuccurullo 2017). These tools enabled us to seamlessly retrieve, process, analyse, and visualise bibliometric data, facilitating a comprehensive examination of the research landscape. One of the key

features of the Bibliometrix package is the ability to build data matrices for co-citation, coupling, scientific collaboration analysis, and co-word analysis. These matrices can help users understand the relationships between articles, authors, and keywords (Aria and Cuccurullo 2017). The package also supports network analysis, a method of analysing the relationships between different nodes in a network. Network analysis can help understand how different articles, authors, and keywords are connected.
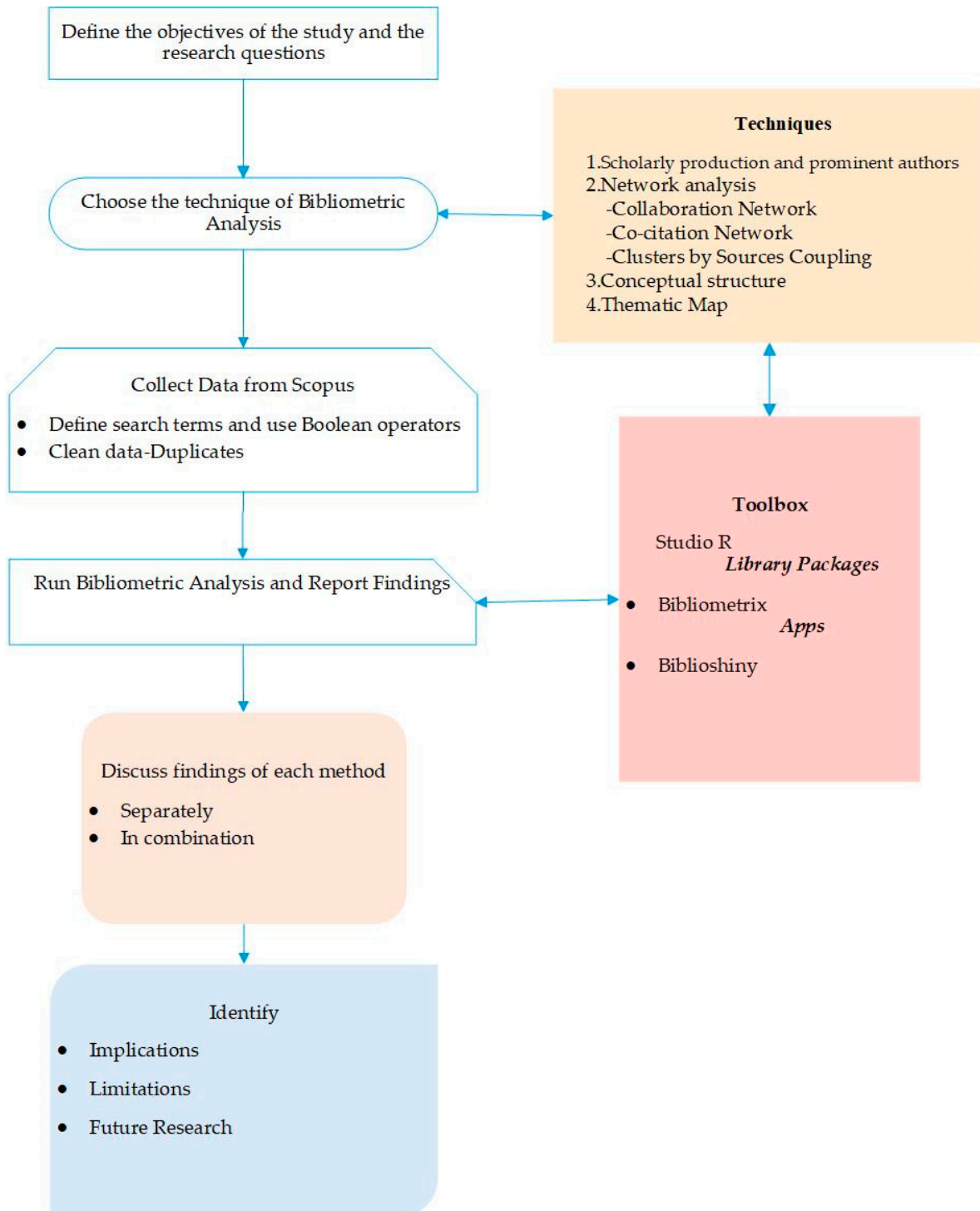

Figure 1. Research framework.

Additionally, Biblioshiny, a web-based interface built on the Shiny app framework, was employed to provide an accessible and user-friendly interface for Bibliometrix. This web interface allowed for generating various visualisations, enhancing the understanding of relationships among authors, publications, and keywords. Visualisations included co-authorship networks, citation maps, and thematic maps, providing valuable insights into the research landscape. Thematic mapping is another feature of the package, which allows users to visualise the relationships between different themes or topics in research. Thematic mapping can help understand how different research areas are related (Clarke and Braun 2017). Factorial analysis, notably correspondence analysis (Greenacre 2017), was employed. Keywords were processed to represent categorical data in a smaller-dimensional space, facilitating the identification of key dimensions affecting procurement processes.

2.2.1. Selection of Database and Search Keywords

In our study, we conducted a comprehensive search for research articles about the integration of ET within the context of PP using Elsevier's Scopus database, a renowned scientific bibliography resource developed in 2004. Scopus is frequently favoured by researchers for its user-friendly features, facilitating the implementation of bibliometric analyses (Liu 2020). While Scopus offers commendable coverage of peer-reviewed journals and publishers, it may overlook relevant documents present in other databases. Interestingly, Scopus tends to yield a higher number of citations per document when compared to Web of Science (Kulkarni et al. 2009; Mongeon and Paul-Hus 2016). We employed a well-structured search query within the Scopus database to retrieve pertinent publications. This query utilised Boolean operators (Scopus Support Center 2023), namely "OR" and "AND, to amalgamate various keywords linked to ET, such as artificial intelligence, blockchain, big data, data analytics, 3D printing, machine learning, business intelligence, augmented reality, robotic process automation, and the Internet of Things. These keywords, enclosed within parentheses and separated by "OR" operators, ensured that our search would encompass articles containing any of these terms. The "AND" operator was employed to conjoin these emerging technology keywords with the specific phrase "PP, which is the focal point of our research.

Consequently, our search exclusively retrieved articles that featured both the emerging technology keywords and the "PP" phrase. We focused our search on the "TITLE-ABS-KEY" field, a customary practice in academic research. This field encompasses the title, abstract, and keywords of articles, allowing us to hone in on the most relevant publications that align with our research topic. Our search was conducted on 18 May 2023, yielding a total of 170 articles. These articles are anticipated to offer valuable insights into the utilisation of ET within the PP domain, shedding light on their impact and implications for procurement processes.

2.2.2. Network Analysis

Network analysis examines and visualises the relationships between publications based on authorship, citations, or common phrases. This capacity bears significance for advancing theoretical understanding and identifying potential areas for future research. Collaboration networks, word co-occurrence networks and citation networks are the three types of bibliometric networks (Batagelj and Cerinšek 2013; Börner et al. 2005; Milojević 2014). Collaboration networks showcase the collaborations between authors, institutions, or groups. Citation networks demonstrate the relationships between publications based on citations. There are three types of citation networks: direct, co-citation, and bibliographic coupling (Yang and Wang 2015). Direct networks connect articles that cite each other, co-citation networks connect articles cited by the same publications, and bibliographic coupling networks connect articles cited by the same authors (Batagelj and Cerinšek 2013; Börner et al. 2005; Milojević 2014; Wang et al. 2015; Boyack and Klavans 2010). These networks can be beneficial in illuminating emerging research trends and "hidden" research communities. Compared to single-authored publications, those written by many authors

have a greater chance of being published in high-impact journals and receiving more citations (Gazni and Didegah 2011). Conversely, multi-authoring and high-impact publishing can vary significantly depending on the research field, the nature of the collaboration, and other contextual factors (Ronda-Pupo and Katz 2018).

2.2.3. Analysis of the Thematic and Conceptual Structure

Thematic maps integrated into bibliometric inquiry allow researchers to investigate a particular discipline's cognitive framework and information domains. These maps offer a graphical overview of the key research themes, subtopics, and interconnections, thus allowing researchers to pinpoint nascent avenues, interdisciplinary partnerships, or research lacunae. Thematic maps further streamline the assessment and elucidation of expansive bibliographic datasets, allowing researchers to acquire insights into the tendencies and progression of knowledge in their respective fields (Börner et al. 2005). Correspondence analysis was employed in this study to unveil the underlying relationships and patterns within a vast array of categorical data, particularly keywords associated with PP and ET (Greenacre 2017). We harnessed the power of the Biblioshiny app, a user-friendly software tool, to execute this analysis (Aria and Cuccurullo 2017). This approach allowed us to effectively reduce the dimensionality of our data, highlighting key dimensions that influence procurement processes.

3. Results

3.1. Scholarly Production and Prominent Authors

Firstly, the annual scientific production in Figure 2 describes the research development on PP and several ETs of ID 4.0. Until 2018, only a few papers were published each year, indicating limited scholarly production. However, since 2018, the number of papers published in the field has grown significantly, indicating researchers' strong interest in PP and ET. The past five years have seen a boom in academic output on PP, and it is anticipated that the number of papers in the field will continue to expand in the years to come. PP, as a tool for sustainable and inclusive growth (Zabala-Iturriagagoitia 2022; Ambe 2019) and as an essential mechanism of modern public governance, will use ET to improve administrative efficiency through the automation of repetitive administrative tasks and provide unprecedented information and analysis regarding spending patterns for better decision-making (Vaidya and Campbell 2016). Also, ET could make PP more transparent (Rodríguez Bolívar and Prados 2022) to help prevent corruption (Modrušan et al. 2021) and increase public trust (Deloitte and European Commission 2020; Wu Chebili et al. 2021).
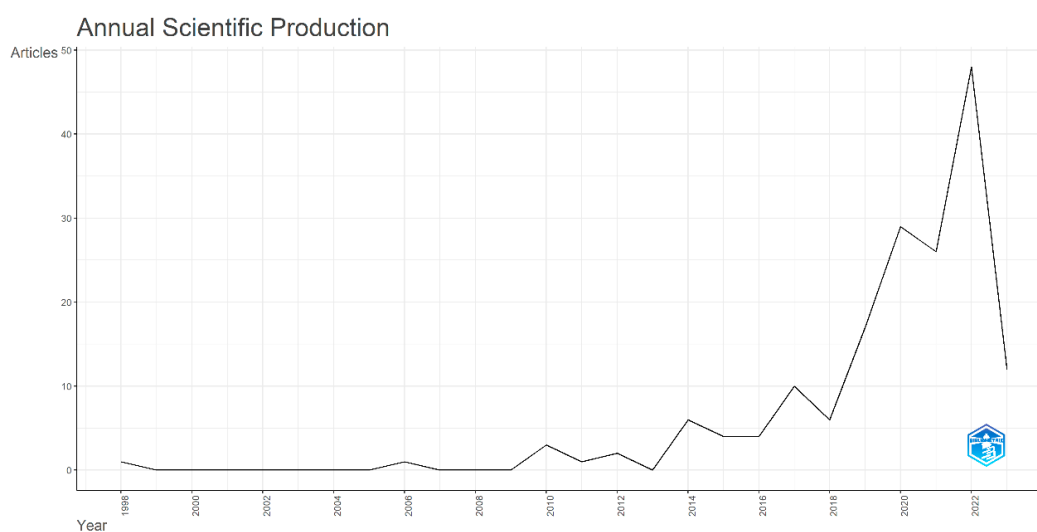

Figure 2. Annual scientific production, PP and ET, 1998–May 2023.

Figure 3 shows that NA has the highest number of articles (16) on the list, indicating a significant volume of work where the author's name is unavailable. Although Fazekas has published six articles, they have a relatively high fractionalised value (2.5), suggesting substantial contributions. Modrušan has published four articles with a fractionalised value of 1.5, indicating consistent contributions. Similar to Modrušan, Rabuzin has published four articles with a fractionalised value of 1.5. Thai KV has published three articles, all of which are fractionalised, suggesting a significant impact.
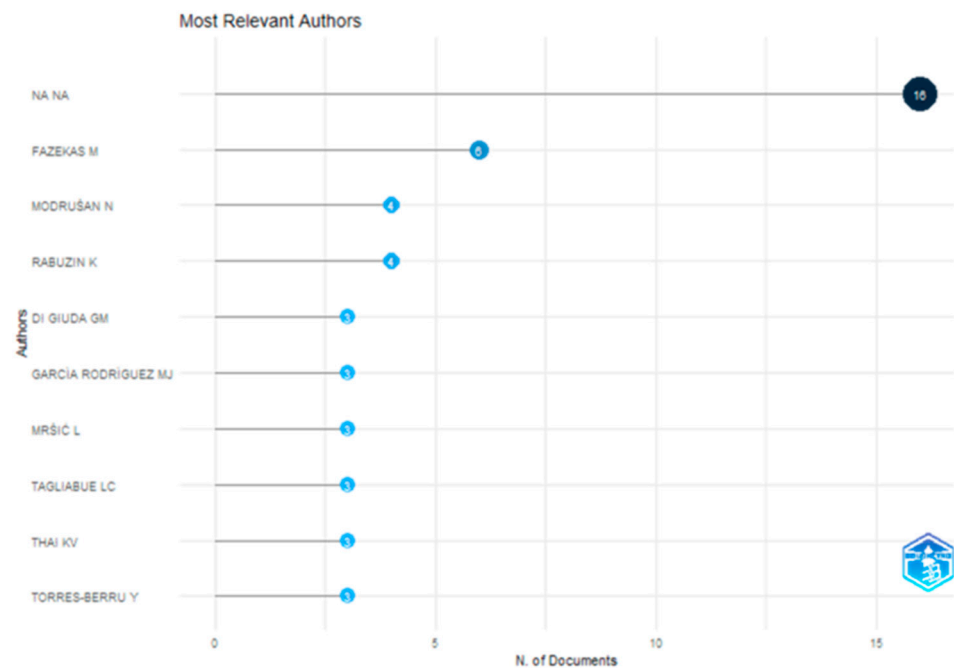

Figure 3. Most relevant authors.

Interpreting the provided publication data in Figure 4, the author "Fazekas M" has a notable publication history in this field, with five publications spanning from 2016 to 2022. Fazekas's publications suggest consistent research activity and expertise. "Modrušan N" and "Rabuzin K" have collaborated on multiple papers in recent years, indicating potential research partnerships. "Torres-Berru Y", "Tagliabue Lc", "Di Giuda Gm", "García Rodríguez Mj", and "Mršić L" have also contributed to the literature in this area, although their publication records are relatively smaller. Identifying the most relevant authors from this list depends on our research's specific criteria and context. Relevant authors can be determined based on various factors, such as the number of articles they have published, the quality and impact of their work, their expertise in a particular subfield, and their recent contributions.

Figure 5 is based on the Scopus database, which indexes academic papers, and it presents the journals that have received the most citations. The most influential journals in the field are the Journal *of* Cleaner Production, the Journal of Public Procurement, Sustainability, IEEE Access, Government Information Quarterly, and the Journal of Purchasing and Supply Management. The Journal of Cleaner Production leads significantly with 54 local citations, which constitutes approximately 24% of the total citations depicted. This indicates a strong influence or relevance of this journal in the field, possibly due to its focus on sustainability and efficiency, which are critical components of emerging technologies in procurement. Notably, there is a substantial gap between the leading journal and the next tier of sources, such as the Journal of Public Procurement and Sustainability, with 32 and 26 citations, respectively. These figures suggest that while there is a range of sources contributing to the discourse, a select few are central to the current research landscape. Furthermore, the clustering of IEEE Access, Government Information Quarterly, and the

Journal of Purchasing and Supply Management, with citations ranging from 18 to 25, indicates that these sources, while less cited than the top tier, still hold a significant place in the scholarly conversation. The presence of diverse journals from different fields, such as Expert Systems with Applications and *Semantic* Web, receiving a similar number of citations (13 and 16, respectively), reflects the interdisciplinary nature of emerging technologies in public procurement, combining insights from information technology, semantic web technologies, and expert systems.
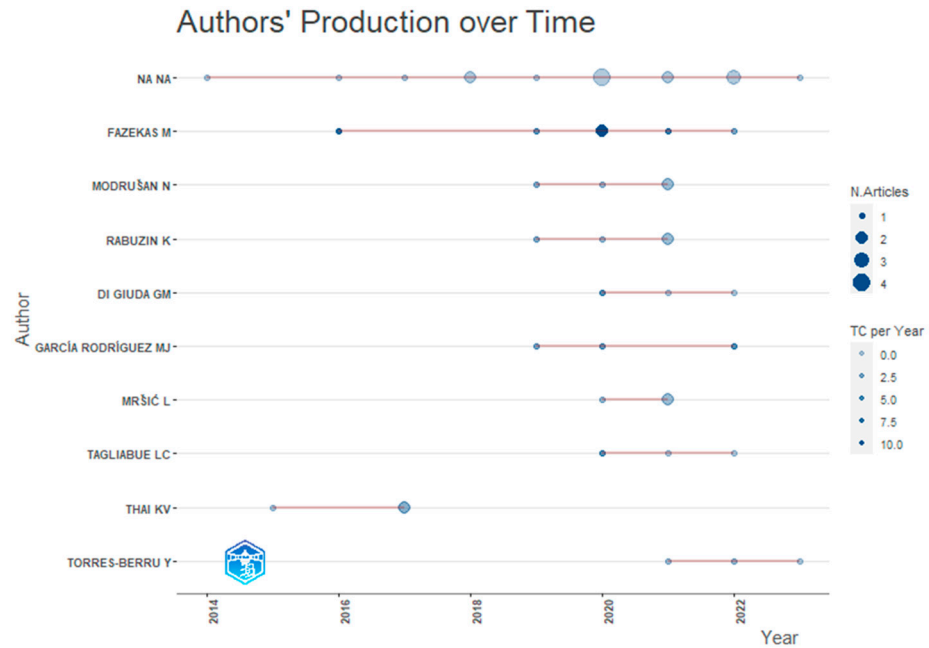

Figure 4. Author's productivity over time.
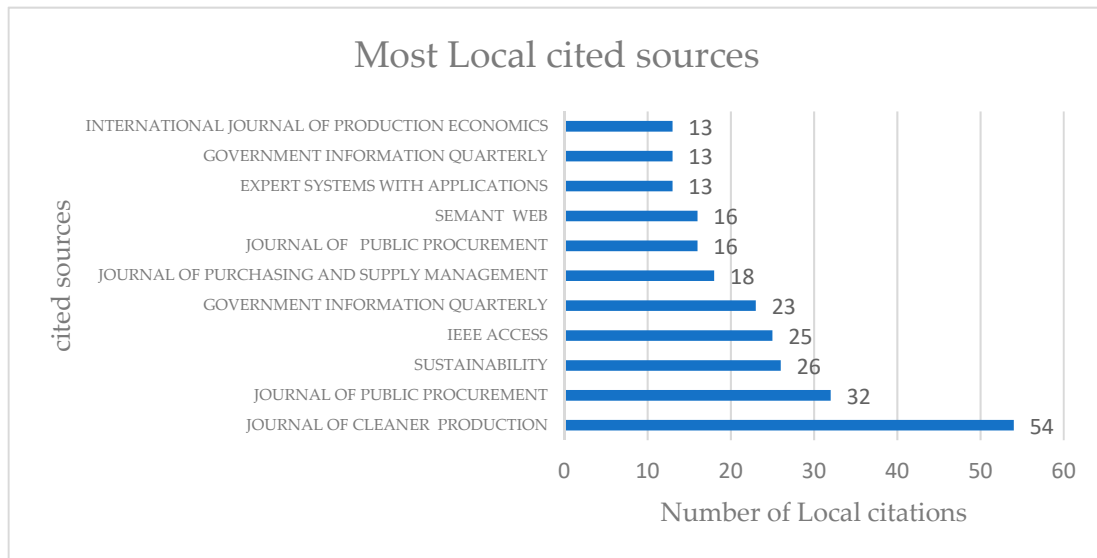
Figure 5. Most locally cited sources.

The h-index, g-index, and m-index of a journal collectively provide insights into its visibility, depth of impact, and consistency in the academic landscape. The h-index and g-index, when applied to comprehensive social science journals, show strong consistency in journal evaluation. These indexes can highlight a journal's academic level and impact, but the h-index cannot be completely replaced by the g-index. When evaluating journals, the h-index and g-index might show stronger consistency compared to the cumulative impact

factor. This could be because both the h-index and g-index are more reflective of the citation impact of articles published in the journal, whereas the cumulative impact factor is a more general measure of journal prestige and may not accurately reflect the impact of individual articles. Regarding the journals listed in Table A1, their varying h-index, g-index, and m-index values indicate different levels of influence and impact in the academic community. For example, Lecture Notes *in* Computer Science has an h-index of 4 and a g-index of 7, suggesting that it has a reasonable influence on some highly-cited papers. Sustainability (Switzerland) has an h-index of 3 but a high m-index of 0.75 (given its recent start year of 2020), indicating emerging influence and growing impact. Lecture Notes in Computer Science (LNCS) has a moderate h-index, indicating a reasonable impact. The g-index is also decent, showing that some of its publications have garnered significant citations. The m-index, which considers both citations and publication count, is relatively low, suggesting that while it has influential papers, it might not consistently produce highly cited work. Sustainability has a relatively high m-index, indicating that it produces influential papers in proportion to its publication count. Its h-index is moderate, suggesting a good overall impact. Despite having a lower number of publications, it has received a substantial number of citations. Complexity has a moderate h-index, indicating a reasonable impact. Its m-index is relatively low, suggesting that it may need more publications to match its citation impact. The European Journal on Criminal Policy and Research has a moderate h-index and a low m-index, indicating that while it has influential papers, it may have room for growth in terms of citations relative to its publication count.

Bradford's Law is an evaluative technique employed in the appraisal of academic journals, which serves to assist researchers in their identification of pertinent journals that feature articles on a particular subject of interest within a designated period. Its origins date back to 1989 when Burrell first introduced it to the scholarly community (Burrell 1989). Bradford's Law rests on the tenet that a minority of journals will present the majority of articles on a given topic, while a more significant number of journals will showcase a lesser number of articles. This principle is commonly referred to as the "core-periphery" model (S. C. Bradford 1934, 1985). We used R-Biblioshiny, a software tool for bibliometric analysis, to apply Bradford's Law to the set of 170 journal articles on PP and emerging technologies indexed in the Scopus database. The categorisation of academic journals into two zones is a protocol whereby the first zone, known as the core zone, comprises a select few journals that are responsible for publishing a significant majority of articles regarding a particular subject matter. In Figure 6, the first zone contained a small number of academic journals that published the majority of articles. The sources are described in Table 1. By identifying the core journals in the field, researchers can better target their literature searches and stay up-to-date with the latest research.

The inclusion of the ranking of journals based on publication frequency helps researchers prioritise their literature search efforts. Journals at the top of the list are likely to be significant sources of research articles in this domain. The "cumFreq" column provides an overview of the total number of articles across the listed journals. This information can give researchers an idea of the overall volume of research available in these journals. The "Zone" classification can be particularly helpful for researchers, as it may indicate the journals' relative importance or impact within the field. Journals in Zone 1 are likely to be the most influential. Table 1 includes a diverse set of journals, not limited to a single academic discipline. This reflects the interdisciplinary nature of research at the intersection of public procurement and emerging technologies.

Researchers can use Table 1 as a starting point for mapping the scholarly landscape in public procurement and emerging technologies. It can guide the selection of journals for comprehensive literature reviews and citation analyses. Lecture *Notes* in Computer Science appears to be the most prolific in terms of scholarly output in the intersection of public procurement and emerging technologies. It is likely a significant source of academic research and should be a primary focus for any researcher in this field. The data from our bibliometric analysis, adhering to Bradford's Law, suggests a concentration of scholarly

output within a core group of journals. This core, represented by Zone 1, includes highly prolific sources such as Lecture Notes in Computer Science and Communications in Computer and Information Science, which collectively account for a substantial share of articles in our research domain. The implication of this finding is twofold. Firstly, it emphasises the significance of these core sources as the foundational literature for researchers and practitioners within the field. The frequent citation of these journals indicates their centrality to the discourse and their potential role in shaping the direction of research and development.
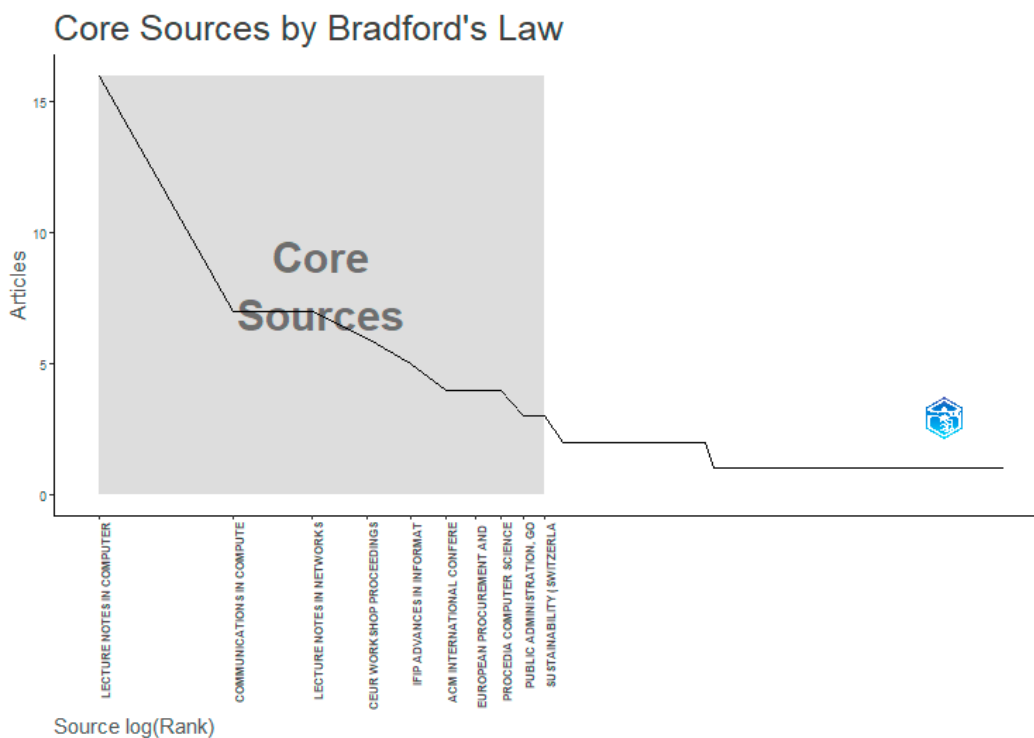

Figure 6. Bradford's Law regarding PP and emerging technologies.

Table 1. Bradford's Law analysis: ranking and frequency of core journals.

Source	Rank	Freq	cumFreq	Zone
Lecture Notes *in* Computer Science	1	16	16	Zone 1
Communications *in* Computer *and* Information Science	2	7	23	Zone 1
Lecture Notes *in* Networks *and* Systems	3	7	30	Zone 1
CEUR Workshop Proceedings	4	6	36	Zone 1
IFIP Advances *in* Information *and* Communication Technology	5	5	41	Zone 1
ACM International Conference Proceeding Series	6	4	45	Zone 1
European Procurement *and* Public Private Partnership Law Review	7	4	49	Zone 1
Procedia Computer Science	8	4	53	Zone 1
Public Administration, Governance *and* Globalization	9	3	56	Zone 1
Sustainability (Switzerland)	10	3	59	Zone 1

Secondly, the presence of numerous journals in Zones 2 and 3, each contributing one or two articles, highlights the breadth of the field. While these sources may not be as central as those in Zone 1, they represent the diversity of research interests and the interdisciplinary nature of the field. They could be sources of niche, innovative, or emerging ideas that might not yet have gained the prominence of the core journals. Bradford's Law helps to identify the most prolific journals within the field of emerging technologies in PP. The journals depicted in the 'Core Sources' section are the most active publishers on the topic. Researchers embarking on literature reviews should prioritize these journals for a comprehensive understanding of the field.

Lotka's Law is suitable for measuring contributors' concentration in the field. We used the Bibliometrix R-package (Aria and Cuccurullo 2017) to apply Lotka's Law (Lotka 1926) to the literature on public procurement and emerging technologies. Figure 7 shows Lotka's distribution, which illustrates the concentration of contributors in the field. According to Lotka's Law, a small number of authors have produced the majority of articles on the subject, which is consistent with findings in other fields of study. The long tail for single-publication authors is also illustrated in Figure 7. In our dataset, Lotka's Law implies that a small percentage of authors (around 10.24%) are highly productive and have contributed the majority of the articles (around 89.76%). The data indicate that the majority of authors (around 89.76%) have only published one article each. Approximately 7.86% of authors have published two articles each, while only 0.24% have published four or more articles.
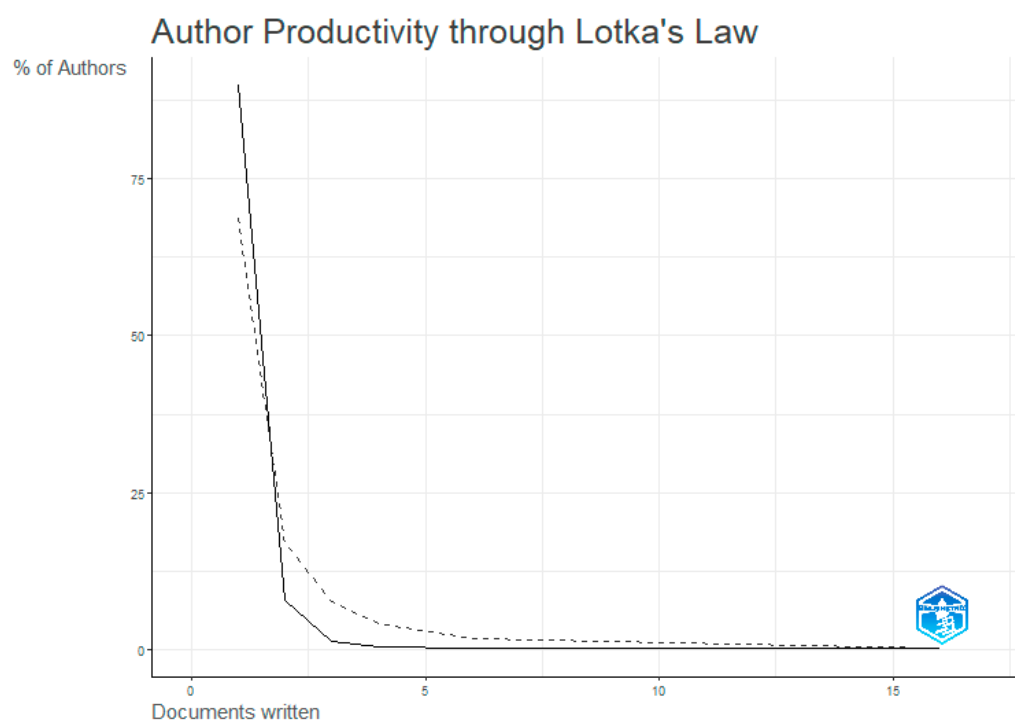

Figure 7. Lotka's Law in PP and emerging technologies research.

3.2. Network Analysis

3.2.1. Collaboration Network

This analysis reveals clusters or communities of authors who frequently collaborate, providing insights into subfields or research groups within the subject. From Figure 8, we understand the patterns of collaboration and knowledge sharing in the PP and ET fields, which can inform us about future research and collaboration efforts (Tam et al. 2023; Su et al. 2020). The visualization in Figure 8 is a collaboration network map illustrating the interconnections among researchers in emerging technologies within public procurement. The red cluster is central to this network, with Nakamura J as a pivotal figure based on the number of connections to other authors, signifying a central role in research collaborations. Adjacent to this is the blue cluster with Marquet D and Schinella S, suggesting potential interdisciplinary collaboration or shared research interests with the central cluster. Peripheral clusters, such as the green cluster with Bergmark P, Höjer M, and Coroama VC, and the orange cluster featuring Kleanthous S and Georgiadis D, indicate specialized groups that may focus on niche areas within the field. These peripheral groups might have fewer interconnections but are nonetheless integral to the diversity and richness of the research landscape. For policymakers, this map is a strategic tool, highlighting key authors for potential engagement and identifying collaborative hubs that could be leveraged to foster innovation and inform policy in public procurement and technology integration.

This network underscores the collaborative nature of scientific research and its implications for informed decision-making in policy and practice.
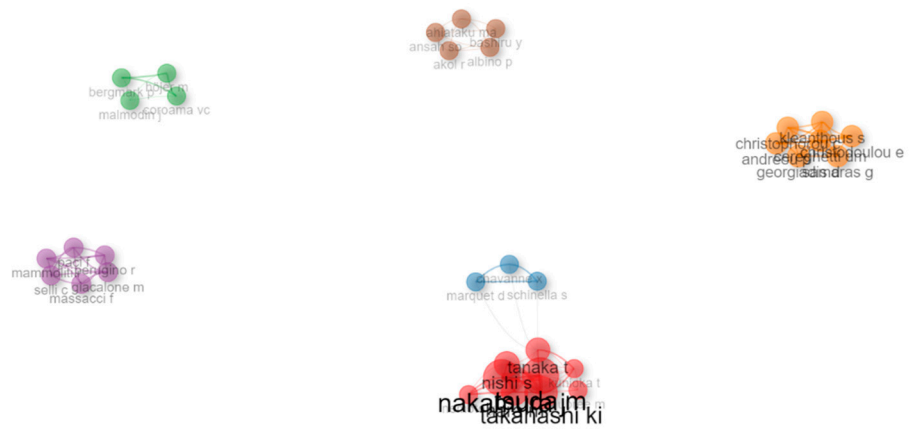

Figure 8. Collaboration network.

3.2.2. Co-Citation Network

The co-citation network in Figure 9 focuses on the co-occurrence of citations between academic papers. The co-citation network is a tool used in social network analysis to identify clusters of authors who frequently collaborate, revealing the interconnections between different research streams. This network, unlike the collaboration network, focuses on the structure of clusters, highlighting shared research interests. The presence of clear clusters in the co-citation network suggests the existence of established knowledge domains or research streams. Authors like Charron and the Fazekas 2016-1 Cluster contribute to these domains, emphasising the importance of building upon existing knowledge within specialised fields. Authors within clusters with higher betweenness and PageRank values, like the Fazekas 2017-1 Cluster, are recognised as intellectual leaders within their respective domains. This paradigm emphasises individual expertise and leadership within specialised areas. The co-citation network highlights well-defined clusters, such as the Fazekas Cluster. This reflects a paradigm where researchers tend to specialise in specific research areas. Authors within these clusters frequently cite each other, indicating deep specialisation within those domains.

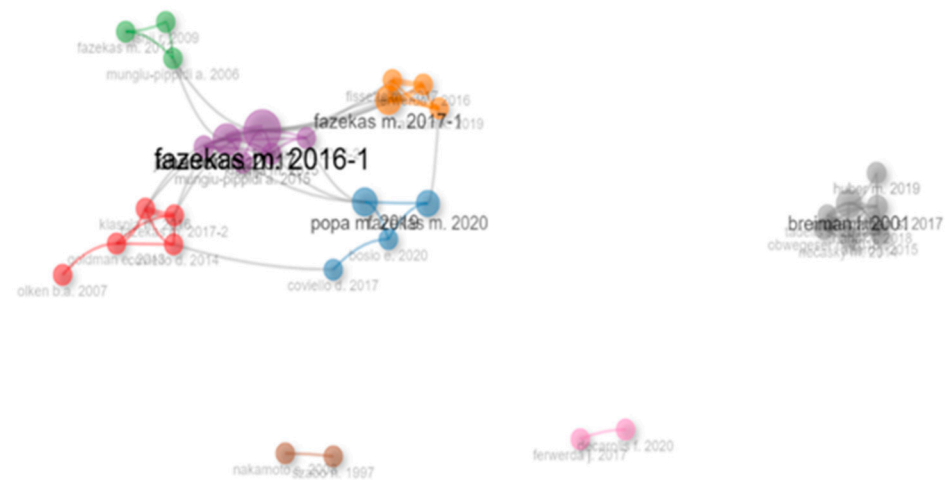**Figure 9.** Co-citation network.

3.2.3. Clusters by Sources Coupling

The collection was generated from the coupling menu of Biblioshiny and is presented in Figure 10. Clusters by sources provide a way to analyse social networks by considering

the patterns of connections between nodes and specific sources. The clustering and coupling of source journals are measured by references and the impact measure of the local citation score (Biscaro and Giupponi 2014). Clusters by sources coupling consider the sources or origins of connections and identify clusters exhibiting similar coupling patterns with specific sources (Boyack and Klavans 2010). In Figure 10, the coupling of source journals showed three clusters. Journals that are central and have high impact, such as Complexity and ACM International Conference Proceeding Series, are positioned towards the top right, indicating their leading role in the field. These sources are not only influential based on citation metrics but also central in connecting different research areas within the field. The journals were ranked as follows, using the high impact measure of the local citation score in each cluster: first, public procurement in Complexity; second, classification of information in the European Journal on Criminal Policy *and* Research; and third, data space in Lecture Notes in *Computer Science*. The sources with high centrality like the European Journal on Criminal Policy and Research in the red cluster indicate that it is well-connected to other clusters, plays a central role in the overall network, and acts as an important intermediary between other sources.
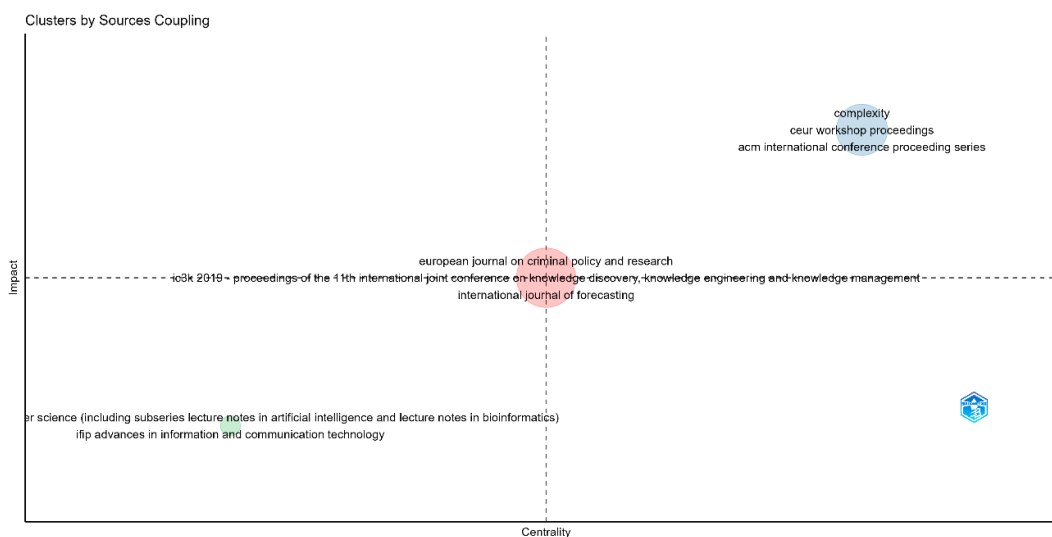

Figure 10. Clusters by sourcing coupling.

3.3. Thematic Maps

3.3.1. Conceptual Structure

To produce a conceptual structure map, we used factorial analysis in Biblioshiny, particularly the correspondence analysis. We employed it to represent categorical data with large dimensions in a smaller dimensional space. Correspondence analysis makes it simpler to find the crucial elements or dimensions that affect the outcomes of procurement processes by improving the interpretation and analysis of difficult bibliometric statistics (Greenacre 2017). In the field, we used KeywordsPlus and removed words like economics, commerce, information use, and linked datum because they have no research interest according to the research objective. Also, we uploaded synonyms to avoid duplicates and overlays like blockchain– blockchain, big data–data analytics, open data–open datum, procurement procedures–procurement–procurement process, and machine learning–machine-learning–machine learning methods. MCA produces results that can be understood by mapping the categories of many variables onto the dimensions/factors. It enables the comprehension of the data's overall structure, the discovery of patterns, and the discovery of correlations between variables. Through testing, we came to the three clusters that explain the relationship between 50 terms by utilising the two most important areas of analysis and research to date: new technologies and PP. In Figure 11, analysing the variables in the first (green) cluster, we found a relationship between big data, the Internet of Things (IoT),

and decision-making. Increased insight into many parts of the procurement procedure can be achieved using big data and IoT. Real-time data on inventory levels, supply chain efficiency, and equipment status can be collected using IoT devices and sensors. When paired with other pertinent statistics, this information can give decision-makers a thorough insight into the procurement process, empowering them to choose suppliers wisely and manage the procurement process accordingly. Ethical considerations and data privacy (Brous et al. 2020) were not found in the cluster, and critical results and objectives using big data and IoT in decision-making, like efficiency, transparency, accountability, and risk management (Adam and Fazekas 2019; AboBakr and Azer 2017), were not found. On the other side, innovation is the critical objective that is presented in the cluster. IoT and big data have the potential to transform procedures through innovative procurement strategies, better supplier selection, and increased accountability, which can result from leveraging data-driven insights, automation, predictive analytics, and collaboration (Gobble 2013; Vassakis et al. 2018; Uddin Murad et al. 2021). This makes sense, particularly related to suppliers' selection. PP authorities can choose the best suppliers by carefully considering data on supplier performance, previous contracts, and compliance records. By ensuring that suppliers with a track record of innovation and quality are considered, this data-driven approach could promote innovation (Wirtz et al. 2019; Cui 2018). In the second (red) cluster, we identified the keywords of blockchain, smart contracts, and transparency that have an obvious relationship and practical explanation (Kamali 2019; Gohil and Thakker 2021). Blockchain suggests a decentralised and immutable ledger for securely recording and storing transactional data, including procurement activities This transparency guarantees that all procurement-related transactions, such as bid submissions, contract agreements, and payment transfers, are permanently recorded and easily audited by relevant stakeholders, which includes government agencies, auditors, and citizens (Rodríguez Bolívar and Prados 2022). The procurement process can be automated and subject to the application of established rules and conditions via smart contracts (Triana Casallas et al. 2020), self-executing contracts recorded on the blockchain. Self-executing contracts eliminate the necessity for intermediaries and decrease the potential of fraud, manipulation, or unapproved changes to the procurement records (Weingärtner et al. 2021; Triana Casallas et al. 2020). Blockchain and smart contracts can have economic and social effects (Mircea et al. 2022). Economic effects, like cost savings for the public finances, could derive from automating processes, reducing paperwork, and eliminating intermediaries. Furthermore, blockchain-facilitated transparent procurement procedures can increase the effectiveness of resource allocation. When public funds are allocated effectively and fairly, the projects and services procured can generate positive externalities such as job creation, infrastructure development, and improved public services (Bailey 2022). Additionally, a greater number of suppliers, especially small- and medium-sized firms (SMEs), can take part in the procurement process by creating an even playing field and decreasing information asymmetry. As suppliers compete to stand out and obtain contracts, increased competition may result in better prices, higher-quality products, and innovation. Social effects could be linked with citizens' trust in public management and politics. By providing accessible and auditable records, citizens can monitor how public funds are being utilised (Triana Casallas et al. 2020). In the third (blue) cluster, we identified two ETs that have related characteristics, artificial intelligence and machine learning. However, it is worth matching these technologies with critical ontological phrases or words such as semantic web, fraud detection, data mining, handling, and classification that make sense in studying the topic. In the context of PP, integrating artificial intelligence (AI) and the semantic web can have significant implications. Significant amounts of data are produced during PP, including information about bids, contract details, supplier information, and performance records (Delina and Macik 2023). Advanced data analysis is made possible by AI techniques and the structured data representation of the semantic web. This involves mining procurement data for patterns detecting and interpreting anomalies (Torres-Berru and López Batista 2021). Additionally, AI-powered systems can use semantic web data to speed up

supplier research and selection for government contracts (Soylu et al. 2019). AI algorithms can find potential suppliers based on particular criteria and requirements by examining supplier profiles, past performance records, certifications, and semantic annotations. AI can help with contract management across the procurement lifecycle when paired with the semantic web (Krichen 2023). AI algorithms can help with contract formulation, review, and monitoring by extracting and organising contract terms, conditions, and obligations (Soylu et al. 2019). AI algorithms may demand responsibilities like spotting potential risks, ensuring rules are followed, and automating contract management duties. Techniques utilising AI and machine learning have extensive potential to improve data processing, classification, and mining in PP. Procurement authorities can improve decision-making, attain actionable insights, and streamline processes using these technologies (Torres-Berru and López Batista 2021; Ovsyannikova and Domashova 2020). To guarantee fairness, openness, and compliance in PP is crucial to ensuring AI systems are properly trained, validated, and aligned with ethical standards (Walshe et al. 2020; Mavidis and Folinas 2022). Natural language processing (NLP) is presented in the cluster and can potentially significantly impact various aspects of PP. NLP techniques can automate document processing tasks, including text extraction, entity recognition, and summarization. This streamlines the review and analysis of procurement documents, improves efficiency, and enhances the accuracy of information extraction. Furthermore, information about suppliers can be analysed using NLP methods from a variety of sources, such as business profiles, financial data, and internet reviews (Burger et al. 2023). Moreover, NLP can effectively analyse contract documents in PP through automation. By studying contract terms, conditions, and obligations, NLP algorithms can support various contract management functions, including compliance verification, risk evaluation, and monitoring (Soylu et al. 2019). NLP presents an opportunity to detect risks and potential fraud in PP.

Figure 11. Conceptual structure map method. Correspondence analysis.
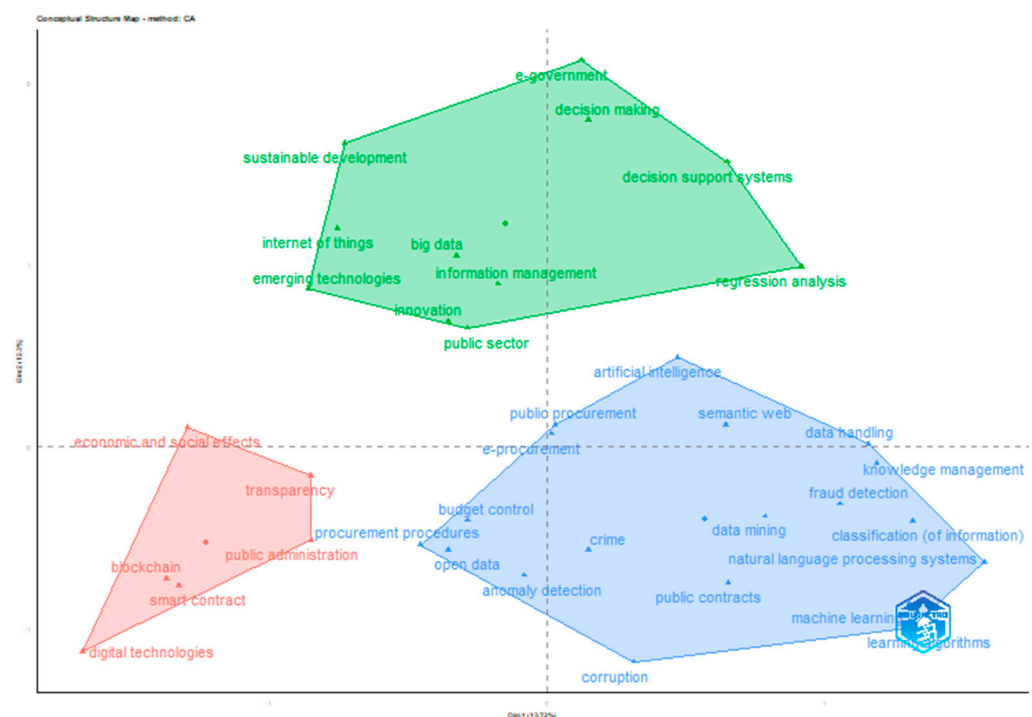
By studying textual data from diverse sources such as procurement documents, emails, and reports, NLP algorithms can pinpoint suspicious patterns, non-conformity issues, or anomalies (Modrušan et al. 2021). By extracting relevant information and identifying trends, NLP algorithms could support market research, supplier identification, and strategic decision-making.

3.3.2. Thematic Map

In Figure 12, the first quadrant identifies motor themes, which are well-developed and important themes for structuring the research field. Machine learning and data mining play a significant role in detecting and preventing crime in PP processes, and this is well established in the bibliography (García Rodríguez et al. 2022; Ash et al. 2021; Modrušan et al. 2021). Plotted in the second quadrant are highly developed and isolated themes, which are themes of limited importance for the field. Niche themes like knowledge graphs and representation have well-developed internal linkages but weak external linkages and are of minimal relevance. In the literature, these topics are also characterised separately and well-developed. Data integration, ontology creation, and proficiency with graph database technologies are needed to implement a knowledge graph in PP. Collaboration between procurement practitioners, data scientists, and domain specialists is essential to create and maintain an effective knowledge graph that answers PP's unique needs and problems. The third quadrant contains emerging or declining themes, which are weakly developed and marginal. Themes like big data, data handling, and cluster analysis indicate emerging trends, innovative approaches, or topics gaining prominence in the research community. The fourth quadrant contains basic and transversal themes, which concern general topics that are transversal to different field research areas. Procurement procedures using blockchain architecture and open data provide a foundation for further analysis and can be combined or overlaid with additional layers to explore relationships and patterns. These topics have the features of low density and high centrality, indicating that although they can impact other topics, they are not entirely established and may inform future research gaps. Highly central and developed themes like "public procurement", "blockchain", and "open data" suggest areas where policies could be focused for immediate impact. Motor themes like "machine learning" and "data mining" are key areas for advancing the field. Niche themes like "knowledge graphs" represent specialized areas that could offer opportunities for unique contributions or innovative research Emerging themes like "big data" indicate where future policy development is needed. The focus on "sustainable development" and "IoT" reflects growing areas of implementation in PP that can improve efficiency and effectiveness. Overall, the map guides all stakeholders on where to concentrate efforts, invest resources, and anticipate future trends for strategic planning and development.
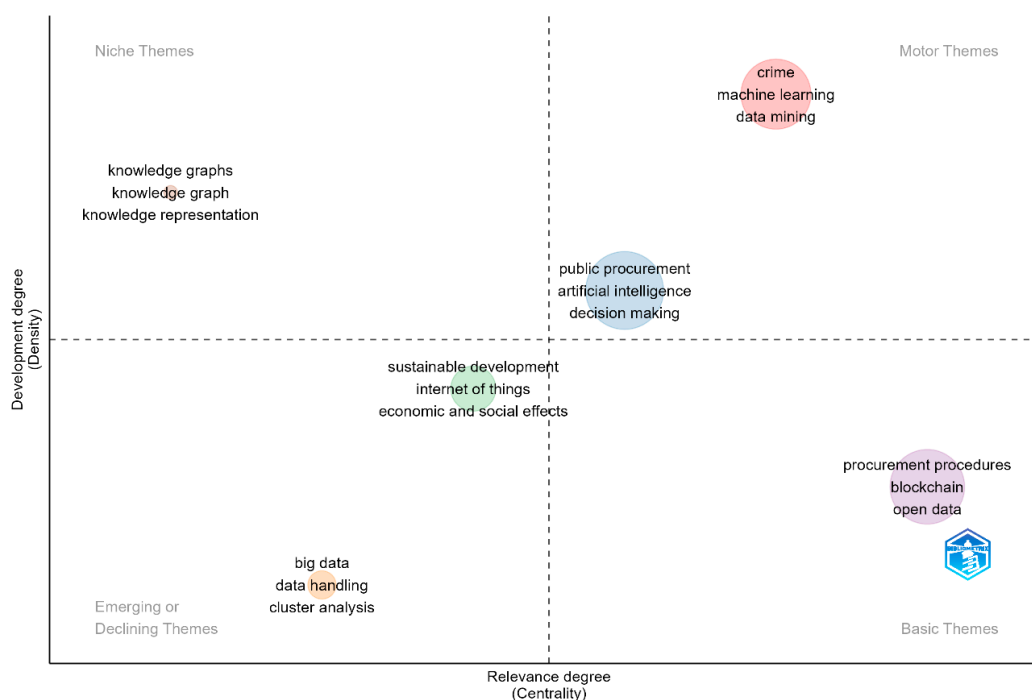

Figure 12. Thematic map.

4. Discussion

The findings show a few significant turning points or inflexion years in the number of papers published in PP and ET. The year 2020 was the most significant turning point regarding the number of papers published. There was a substantial increase to 48 papers, which may be attributed to various factors, including the growing significance of ET, increased funding for research, or broader recognition of the field's importance. ET, such as artificial intelligence, blockchain, and IoT, are advancing quickly, creating new opportunities and challenges in PP (Ubaldi et al. 2019; Zamani et al. 2022). Researchers may have responded to this trend with increased research output. Increased funding or research grants in this field could have incentivised researchers to conduct more studies (Deloitte and European Commission 2020; Ubaldi et al. 2019). Changes in government policies and regulations related to PP and ET may have spurred research in this area (European Commission 2019; Deloitte and European Commission 2020; American Council for Technology and Industry Advisory Council (ACT-IAC) 2021; Gailhofer et al. 2021; Stahl et al. 2022). Ranking the five most important journals based on the metrics are:

1. Lecture Notes in Computer Science
2. Sustainability
3. European Journal on Criminal Policy and Research
4. Lecture Notes in Networks and Systems
5. Proceedings—18th IEEE/ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing, SNPD 2017

The rankings are based on the available metrics and considerations, but the importance of a journal may vary depending on the specific research focus within the field of public procurement and emerging technologies. It is advisable to review the content of these journals to determine their relevance to each research. Also, the importance of a journal can change over time, so staying updated on recent publications and developments in the field is crucial. Na, Fazekas M, Modrušan N, Rabuzin K, Thai Kv, Mršić L, and Torres-Berru Y have published multiple articles, and their fractionalised values indicate that their work is impactful and relevant. However, it is important to note that the relevance of authors can vary depending on the specific research focus and the subfield of PP and ET in question. Thus, we have to consider reviewing the content of their articles to assess their expertise and the alignment of their work with our research interests. The eight co-citation networks reveal the intellectual structure of the field by identifying groups of authors who frequently co-cite each other's works. These clusters likely represent research communities or subfields within the broader topic of PP and ET. The presence of Fazekas in multiple clusters suggests that this author plays a significant role in bridging different research communities or themes within the field. Authors like Fazekas M with high PageRank scores have a substantial influence on the network, indicating that their works are frequently cited by others (Small 1973). The presence of authors like Fazekas M and Popa M with high centrality suggests that they may act as intermediaries or connectors between different research streams, facilitating the flow of ideas and collaborations (Small 1973).

The co-citation network and the collaboration network are two key tools used in research. These networks help institutions identify potential research leaders, foster collaboration, and reward researchers, enhancing their impact in specific research domains. In the collaboration network, central figures like Nakamura J emerge as significant influencers, suggesting leadership or a bridging role among research clusters. Peripheral clusters, including Bergmark P and Höjer M in the green cluster and Kleanthous S in the orange cluster, indicate specialized niches contributing to a broader research dialogue. This network visualization informs policymakers of key contributors and highlights collaborative patterns essential for advancing the field and shaping future technological integration in public procurement policies. Co-citation is useful for domain-specific excellence and collaboration for fostering broader connections (Small 1973; Batagelj and Cerinšek 2013). Recognising and supporting researchers who bridge the gap between different paradigms, as seen with authors like Bosio and Fazekas, can be crucial for advancing interdisciplinary

and specialised research. Researchers may need to navigate their career paths by considering whether they want to excel within specialised domains, exemplified by authors like Charron and the Fazekas 2016-1 Cluster, or contribute to broader, interdisciplinary fields. Institutions and researchers could strike a balance between promoting interdisciplinary collaboration, exemplified by the Mungiu-Pippidi and Fazekas Clusters, and recognising the value of specialised expertise within clusters. From the results of the correspondence analysis, keywords that cluster closely together on the graph share similarities in their co-occurrence patterns within the dataset. For instance, "blockchain", "public administration", and "transparency" form Cluster 2, suggesting a thematic association between blockchain technology and aspects of public administration and transparency.

Conversely, "e-government", "innovation", and "knowledge management" cluster in Cluster 3, indicating a relationship between these concepts within the context of ET and PP. These findings can inform the development of future research questions and guide a deeper exploration of the relationships between ET and PP processes. The findings from the thematic map about PP and ET provide valuable insights into the landscape of research in this field. The strong presence of machine learning and data mining in the first quadrant indicates that these themes are well-established and crucial for PP. Knowledge graphs and representation in the second quadrant suggest that while these themes are well-developed internally, they lack strong external linkages and may have limited relevance to the broader field. Collaboration between stakeholders, including procurement practitioners, data scientists, and domain specialists, is essential to bridge the gap between well-developed internal knowledge and its practical application in PP. The third quadrant highlights emerging trends in big data, data handling, and cluster analysis, indicating innovative approaches gaining prominence in the research community. These emerging trends may lead to new methodologies and tools for handling and analysing large datasets in PP. Quadrant four showcases themes like procurement procedures using blockchain architecture and open data, which can potentially impact various research areas within PP. Collaborative efforts among researchers, policymakers, and practitioners are vital for harnessing the full potential of these transversal themes. The correspondence analysis unveiled how specific emerging technology terms co-occur within the procurement context, emphasising the relevance of AI, machine learning, and data mining.

Meanwhile, the thematic map illuminated broader thematic trends, highlighting the significance of sustainable development and energy efficiency in integrating technology. These findings collectively suggest that integrating ET, particularly artificial intelligence, is pivotal in shaping contemporary PP practices. Also, this comprehensive view aids in understanding the multifaceted nature of technology adoption in PP, offering valuable insights for researchers and policymakers alike to drive innovation, transparency, and efficiency in this critical domain. Commenting on the collaboration network concerning the thematic map, we did not identify similarities in authors and topics in the following areas: artificial intelligence, artificial intelligence governance, and sustainable development.

4.1. Implications of the Bibliometric Analysis

Figure 2 of annual scientific production reveals a noteworthy escalation in research output, culminating in a peak in 2021. This trend may reflect a burgeoning interest or a pivotal development in the field, suggesting a period of concentrated academic attention and possibly innovation. Understanding these fluctuations is crucial for strategic planning in research development and may guide future investigations into the factors influencing these patterns. To determine the most relevant sources for future research in the field, it is crucial to consider several factors, including the focus of our research, the specific topics we are investigating, and the quality and impact of the journals. We could make some recommendations based on factors like the sources' impact metrics and citation count. The bibliometric analysis indicates a significant local research interest in sustainable practices within public procurement, as evidenced by the Journal of Cleaner Production receiving the highest number of citations. This trend reflects a regional prioritisation of sustainability

and efficiency in integrating emerging technologies into procurement processes. The diverse range of cited sources, including journals focused on information technology and management, points to an interdisciplinary tactic to addressing the complexities of public procurement. It further implies that local academia and practitioners actively contribute to the global dialogue on sustainable procurement, with a clear inclination towards innovative, cleaner production methodologies. This citation pattern may influence future research directions and policy-making within the region.

Additionally, Lecture Notes In Computer Science appears to be influential, with a moderate h-index and g-index. It may be relevant if the research aligns with computer science and artificial intelligence topics. The relevance of a source depends on our specific research objectives and the alignment of the journal's content with the research topics.

Furthermore, the most locally cited journals can facilitate collaboration opportunities. Local citation patterns can provide insights specific to a particular context or region. Therefore, it is especially important when the adoption and implications of emerging technologies in public procurement vary by location due to different regulatory environments, economic conditions, or technological infrastructures. The frequency of citations in journals like the Journal of Cleaner Production and Sustainability suggests a strong local focus on environmental and sustainable practices. Policymakers could infer that integrating sustainability considerations into procurement policies may have substantial support and interest within the community. The repeated citation of Government Information Quarterly indicates a reliance on governance and information dissemination practices, implying that transparency and effective communication are key areas of interest and concern. For researchers and policymakers, Figure 5 suggests a significant community engagement with the themes of sustainability, technology, and governance in procurement. Citations in Government Information Quarterly and the Journal of Public Procurement highlight the importance of policy research in procurement processes. Policymakers could use findings from these journals to inform regulations that ensure fair and efficient procurement, particularly when dealing with rapidly changing technologies. Collaborative efforts between these groups could lead to the development of forward-thinking policies grounded in solid research, ensuring that public procurement acts as a catalyst for adopting emerging technologies while also upholding sustainable practices.

The bibliometric analysis utilised Bradford's Law to study publication patterns and analyse the impact and visibility of publications. Bradford's Law is a principle that provides insight into the distribution of scientific literature across journals. Analysing the specific dataset provided in Table 1, we observed that Zone 1 encompasses journals ranked 1 to 10, cumulatively containing 59 articles. This zone represents the core journals in the field, with Lecture Notes in Computer *Science* being the most prolific, contributing 16 articles. These core journals are critical as they hold a substantial proportion of the subject's literature, signifying their centrality for researchers. Zone 2 extends from ranks 11 to 24, where the cumulative frequency increases by 22 articles to a total of 85. This increment signifies a decline in the density of relevant articles, indicating these journals are less central but still significant. Zone 3 comprises journals ranked 25 and beyond, each contributing only 1 article, which indicates a steep drop-off in relevance. This zone characterizes the long tail of the literature distribution, where numerous journals contribute marginally to the overall corpus. The strategic value derived from applying Bradford's Law to this dataset is multifaceted. For researchers, focusing on Zone 1 journals can maximize efficiency in literature retrieval, as these are likely to contain the majority of relevant articles. For libraries and information centres, prioritizing subscriptions and access to Zone 1 journals can significantly support the research needs of their patrons. Additionally, bibliometric analyses benefit from identifying key journals, as these can often correlate with the impact and influence within the field. Bradford's Law thus serves as a guiding principle for resource optimization in scholarly communication and information retrieval.

Lotka's Law suggests that a few authors or researchers are highly productive, while many authors contribute fewer publications. Several factors can explain the long tail for

single-publication authors. Numerous scholars might limit the number of papers they contribute by concentrating their efforts on a single subject or area of specialisation. Moreover, because they have less experience in the area, early career researchers and scholars in the early phases of their academic careers frequently publish less. However, single-publication authors could contribute new insights, creative concepts, or crucial discoveries that could greatly impact their areas. Also, emerging technologies develop rapidly, making it difficult for authors of single publications to keep up and generate a significant number of publications (Qiu et al. 2017; Allison et al. 1976). Emerging technologies often require specialised knowledge and expertise, leading to fewer highly productive authors at the forefront of innovation. In network analysis, the collaboration network highlights researchers who play central roles in the field as "key players".

Analysing the structure of the collaboration network can reveal important information about the patterns and nature of collaborations. There are nodes like Nakamura with high centrality, which are considered to be more important in the network than nodes with low centrality. The presence of six distinct clusters or communities of authors in the co-citation network suggests that there are specific groups of researchers who frequently collaborate. Therefore, that collaboration plays a significant role in advancing research in this field. Institutions and funding bodies may consider supporting interdisciplinary collaborations to foster innovation at the intersection of public procurement and emerging technologies. By examining the clusters by sourcing coupling, we detected the high-impact journals which introduce new ideas and approaches that could be adopted by other researchers in the field. These trends can significantly impact the direction of research in the field. Engaging with these high-impact sources would be a priority for researchers who want to stay current on advancements in their subject. Clustering analysis can drive new insights, methodologies, and solutions for enhancing public procurement processes. In a thematic map, transversal themes are those that have the potential to impact multiple research areas within a particular field. In this case, the transversal themes are procurement procedures utilising blockchain architecture (Jory Heckman 2018) and open data (Mircea et al. 2022). The identified clusters and their corresponding themes within the conceptual structure map of public procurement and emerging technologies have several implications. The analysis highlights how the utilisation of big data and IoT can provide real-time insights into various aspects of the procurement process, such as inventory levels, supply chain efficiency, and equipment status.

Blockchain and smart contracts can improve transparency and efficiency in public procurement, leading to cost savings, improved resource allocation, and increased participation of SMEs (Omar et al. 2021). Additionally, emerging technologies can improve efficiency, accuracy, and effectiveness in public procurement processes through data-driven insights, automation, and collaboration, leading to better supplier selection, improved decision-making, streamlined processes, and enhanced contract management. The thematic map can help researchers identify research gaps and opportunities. Themes in Quadrants 2 and 3, despite their isolation or emergence, may provide opportunities for innovative research. Researchers can use the map as a guide to prioritise well-established research areas (Quadrant 1) and those with growth potential (Quadrants 3 and 4) (Cahlik 2000; Cobo et al. 2011, 2015). The thematic map underscores the importance of interdisciplinary collaboration in public procurement and emerging technologies. Researchers should engage in cross-disciplinary collaboration to address complex challenges and make the most of emerging trends. For example, data scientists can collaborate with procurement professionals to implement knowledge graphs effectively (Cobo et al. 2011, 2015; Clarke and Braun 2017).

4.2. Key Findings and Implications

Table 2 summarizing the key aspects, their key points, and implications from the analysis of the research field:

Table 2. Overview of research trends in public procurement and emerging technologies.

Aspect	Key Points	Implications
Annual Scientific Production	Notable increase in research output, peaking in 2021. Reflects growing interest and possibly innovation in PP and ET.	Understanding these trends is vital for strategic research planning and may guide future investigations.
Prominent Authors and Journals	Journals like the Journal of Cleaner *Production* lead in citations, suggesting a focus on sustainability. Authors like Fazekas and Modrušan are noted for significant contributions.	The impact and quality of journals and authors guide researchers in identifying relevant sources for their work.
Local Citation Patterns	The prevalence of citations in journals like the Journal of Cleaner Production and Sustainability suggests a strong research interest in the intersection of public procurement and sustainable practices.	Policymakers could leverage this information to promote green procurement policies that prioritize environmentally friendly technologies.
Collaboration Network	Key players like Nakamura J in the collaboration network indicate central roles. Six distinct clusters suggest specific collaboration groups.	Collaboration network analysis can reveal collaborations' patterns and nature, guiding future research partnerships.
Research Themes and Opportunities	Transversal themes like blockchain in procurement indicate potential impactful research areas. Interdisciplinary collaboration emphasized.	Thematic maps help identify research gaps and opportunities, emphasizing the importance of interdisciplinary collaboration.

4.3. Limitations

Bibliometric analysis is a valuable tool for identifying influential authors and journals within a specific research field, but it has certain limitations that researchers should be aware of. The influence of a journal can vary over time and across different subfields. To assess these journals' current influence and reputation, we consult academic databases and citation analysis tools and seek input from experts in the field. Bibliometric databases may not include all relevant publications, especially those from non-English sources or journals that are not widely indexed. This can lead to a bias in the results, favouring authors and journals from well-represented regions and languages (Belter 2015; Wallin 2005). Citation impact takes time to accumulate. Newly published articles or journals may not have had sufficient time to accrue citations, leading to their influence being underestimated. High citation counts do not necessarily equate to high-quality research (Wallin 2005). Some influential works may receive numerous citations due to their popularity or controversial nature rather than their scientific accuracy (Hicks et al. 2015). Negative citations, where a work is cited to criticise or refute it, are essential for scholarly discourse but may not be captured in traditional bibliometric analyses focused on positive citations (Belter 2015; Wallin 2005; Hicks et al. 2015; Romanelli et al. 2021). Bibliometric studies only offer a fragmentary view of the area they are researching since they use a small number of bibliometric methodologies and data in a research field that is in progress (Donthu et al. 2021).

The Bradford's Law categorisation process in core and peripheral zones is subjective and can vary depending on the researcher's perspective. Some researchers have suggested employing quantifiable indicators of journal quality, like citation counts or impact factors, in addition to subjective categorisation, to address this issue (Brady and Cronin 2001). These metrics, however, also have drawbacks and might not adequately reflect the complexity of the research ecosystem.

Lotka's Law does not consider the quality or impact of the cited publications but focuses solely on the distribution of citations. A journal or publication may receive many citations, but this does not necessarily indicate that the research published within that journal is of high quality or significance (Allison et al. 1976). When assessing the quality

and importance of a publication, it is crucial to consider other aspects, such as peer review, the reputation of the authors and the journal, and the study method and findings. Understanding the dynamics of a given field of research and the contributions of individual academics to its development requires an important tool: tracking the productivity of top writers over time.

Nevertheless, analysing only the work of highly productive and influential authors may exclude other researchers who are also making valuable contributions to the field but may not be as well-known or productive. Quantitative data may not capture the quality or impact of the publications produced by top authors. Qualitative assessments such as peer review or expert opinions can be used (Noyes et al. 2019).

Public procurement in emerging technologies involves interactions between the public sector and industry, which means both parties are involved in developing and implementing new technologies. As a result of these interactions, there may be a significant number of non-academic publications, such as industry reports, policy documents, or whitepapers, produced by both the public sector and industry. Including non-academic sources in the analysis of author productivity may require adjustments or alternative approaches, as these sources may not follow the same patterns as academic publications. In network analysis, another limitation is that the strength or intensity of collaboration is not always implied by the mere fact that it exists in a network.

Moreover, clustering analysis may not provide contextual information about the content or quality of the publications. Researchers need to combine clustering analysis with qualitative assessments. When using correspondence analysis to analyse the conceptual structure in bibliometric analysis, there are some specific limitations to consider, such as simplification, which may result in the loss of some subtle nuances and complexities present in the original data. In addition, if certain terms are used more frequently than others, they may dominate the analysis and skew the results. This can potentially overshadow the importance of a dataset's less frequently used yet still significant terms. Researchers can address this issue using techniques such as weighting or scaling to adjust for the frequency of occurrence of terms in the dataset. Similarly, correspondence analysis can tell us which terms are related to each other, but it cannot tell us why they are related or what they mean. Consequently, additional qualitative analysis or domain expertise is required.

Limitations of the thematic map analysis include a potential oversimplification of complex relationships between themes. It may not capture nuanced interactions between emerging technologies and public procurement, as it relies on predefined keywords (Clarke and Braun 2017). Additionally, the thematic map may not reflect the evolving nature of research, potentially missing emerging trends (Cobo et al. 2011). It lacks the granularity to assess the strength of associations between themes. Furthermore, while it identifies thematic clusters, it does not delve into the underlying reasons for these associations (Gentilli 1997). Researchers should exercise caution when interpreting these results and consider supplementary analyses for a more comprehensive understanding of the intricate dynamics between public procurement and emerging technologies.

5. Conclusions

The conclusion of this bibliometric analysis on emerging technologies (ET) in public procurement (PP) encapsulates the evolution and current state of scholarly production, the prominence of key authors and journals, and the implications of these findings for policymakers and researchers. The significant increase in research output since 2018 underscores a burgeoning interest in ET within PP. This uptick, peaking notably in 2021, aligns with the strategic emphasis on digital transformation and innovation in governance. Publications have proliferated, reflecting a collective academic response to the pressing need for transparency, efficiency, and modernization in public sectors globally. The scholarly community has recognized the potential of PP as a catalyst for sustainable growth. Journals like the Journal of Cleaner Production, the Journal of Public Procurement, and

Sustainability have emerged as influential, with their high citation counts signifying their central role in shaping the academic discourse around PP and ET.

Bradford's Law reveals that a small number of journals publish the majority of influential articles, suggesting that these core journals are essential reading for those in the field. Collaboration network analysis has unveiled vital connections among researchers, indicating robust collaborations that likely drive innovation in the field. For instance, Nakamura J's central position in the network map points to a key role in fostering research partnerships, suggesting that engagement with such authors could yield rich, collaborative insights. Authors like Fazekas, Modrušan, and Thai KV have made significant contributions to the field, as evidenced by their high fractionalized values and consistent research activity. The co-citation network and clusters by sources coupling have further dissected the research landscape, identifying influential authors and clusters central to the field's development. Influential authors and journals assist in recognizing intellectual leadership and understanding how ideas and innovations are disseminated within the community.

The analysis reveals relationships between emerging technologies and procurement processes using correspondence analysis and thematic maps. It identifies key themes like big data, IoT, blockchain, and smart contracts, and discusses their implications for procurement, such as enhanced decision-making, transparency, and efficiency. Collaborative networks and thematic clusters identified in the analysis emphasize the interdisciplinary nature of the field and the potential for future research and policy development. As the field continues to evolve, stakeholders should focus on these influential areas and contributors to leverage the full potential of ET in public procurement, aiming for transparency, efficiency, and sustainable growth.

The bibliometric analysis provides a valuable snapshot of the PP and ET research landscape, highlighting key journals, authors, and trends. However, limitations exist, including potential biases toward well-indexed journals, overlooking non-English and non-academic works, and the possible overemphasis on quantity over quality of citations. Careful consideration of these limitations is essential for a nuanced interpretation of the results and for guiding future research directions.

In conclusion, this bibliometric analysis serves as a strategic compass, pointing policymakers and researchers to the core journals, prominent authors, and pivotal themes shaping the intersection of PP and ET. It underscores the critical role of interdisciplinary collaboration in driving the field forward and the importance of a nuanced approach in leveraging these insights for policy formulation and research advancement. For the research community, staying abreast of the most cited journals and engaging with the central figures in the collaboration network could significantly influence the trajectory of their work. For policymakers, these insights offer a roadmap to harness the expertise of leading researchers to inform evidence-based policy decisions, particularly in harnessing ET to achieve transparent and efficient procurement processes.

Appendix A

Table A1. Source local impact.

Element	h_Index	g_Index	m_Index	TC	NP	PY_Start
Lecture Notes *in* Computer Science (including Subseries Lecture Notes *in* Artificial Intelligence and Lecture Notes *in* Bioinformatics)	4	7	0.30769231	53	16	2011
Sustainability (Switzerland)	3	3	0.75	102	3	2020
Complexity	2	2	0.4	27	2	2019
European Journal *on* Criminal Policy *and* Research	2	2	0.25	88	2	2016
Ic3k 2019—Proceedings *of the* 11th International Joint Conference *on* Knowledge Discovery, Knowledge Engineering *and* Knowledge Management	2	2	0.4	13	2	2019
Lecture Notes *in* Networks *and* Systems	2	2	0.5	7	7	2020
Procedia Computer Science	2	3	0.5	9	4	2020
Public Administration, Governance *and* Globalization	2	2	0.22222222	5	3	2015
2017 40th International Convention *on* Information *and* Communication Technology, Electronics *and* Microelectronics, *MIPRO* 2017—Proceedings	1	1	0.14285714	20	1	2017
2020 7th International Conference *on* E-democracy *and* E-government, *ICEDEG* 2020	1	1	0.25	6	1	2020
2022 21st International Symposium *INFOTEH-JAHORINA, INFOTEH* 2022—Proceedings	1	1	0.5	2	1	2022
ACM International Conference Proceeding Series	1	2	0.14285714	4	4	2017
Advances *in* Intelligent Systems *and* Computing	1	1	0.25	1	2	2020
AI and Society	1	2	0.25	18	2	2020
Applied Sciences (Switzerland)	1	1	0.5	1	1	2022
Automation *in* Construction	1	1	0.5	9	1	2022
Business *and* Politics	1	1	0.2	7	1	2019
CEUR Workshop Proceedings	1	1	0.1	1	6	2014
Communications *in* Computer *and* Information Science	1	2	0.16666667	6	7	2018
Computers	1	1	0.33333333	10	1	2021
Data 2020—Proceedings *of the* 9th International Conference *on* Data Science, Technology *and* Applications	1	1	0.25	4	1	2020

Table A1. *Cont.*

Element	h_Index	g_Index	m_Index	TC	NP	PY_Start
ECEEE Summer Study Proceedings	1	1	0.2	1	1	2019
Economic Computation *and* Economic Cybernetics Studies *and* Research	1	1	0.33333333	2	1	2021
Electronics (Switzerland)	1	1	0.33333333	2	1	2021
Energy Policy	1	1	0.25	21	1	2020
Environmental Innovation *and* Societal Transitions	1	1	0.5	2	1	2022
Equilibrium. Quarterly Journal *of* Economics *and* Economic Policy	1	1	0.5	1	1	2022
EU Energy Policy Towards *the* 21st Century	1	1	0.03846154	3	1	1998
European Journal *of* Comparative Law *and* Governance	1	1	0.2	4	1	2019
European Procurement *and* Public Private Partnership Law Review	1	2	0.2	8	4	2019
Frontiers *in* Artificial Intelligence *and* Applications	1	1	0.07142857	1	1	2010
Frontiers *in* Climate	1	1	0.33333333	2	1	2021
Frontiers *in* Energy Research	1	2	0.25	17	2	2020
Governance	1	1	0.5	5	1	2022
IET Conference Publications	1	1	0.16666667	23	1	2018
IFIP Advances *in* Information *and* Communication Technology	1	2	0.07142857	5	5	2010
Information (Switzerland)	1	1	0.5	7	1	2022
Information Visualisation—Biomedical Visualization, Visualisation *on* Built *and* Rural Environments *and* Geometric Modelling *and* Imaging, *IV* 2018	1	1	0.16666667	7	1	2018
International Archives *of the* Photogrammetry, Remote Sensing *and* Spatial Information Sciences—*ISPRS* Archives	1	1	0.25	1	2	2020
International Handbook *of* Public Procurement	1	1	0.14285714	12	1	2017
International Journal *of* Advanced Computer Science *and* Applications	1	1	0.33333333	3	1	2021
International Journal *of* Data Science *and* Analytics	1	1	0.33333333	18	1	2021
International Journal *of* Decision Support System Technology	1	1	0.11111111	4	1	2015
International Journal *of* Engineering *and* Technology (UAE)	1	1	0.16666667	1	1	2018
International Journal *of* Forecasting	1	2	0.33333333	14	2	2021
International Journal *of* Scientific *and* Technology Research	1	1	0.2	10	1	2019
International Journal *of* Software Engineering *and* Knowledge Engineering	1	1	0.08333333	38	1	2012
International Journal *of* Technology Management	1	1	0.07142857	22	1	2010
International Organisations Research Journal	1	1	0.2	3	1	2019

Table A1. *Cont.*

Element	h_Index	g_Index	m_Index	TC	NP	PY_Start
International Transactions *in* Operational Research	1	1	0.33333333	14	1	2021
IOP Conference Series: Earth *and* Environmental Science	1	1	0.2	4	1	2019
Journal *of* Information Technology *and* Politics	1	1	1	1	1	2023
Journal *of* Physics: Conference Series	1	1	0.25	8	1	2020
Journal *of* Public Procurement	1	1	0.5	4	1	2022
Lecture Notes *in* Business Information Processing	1	1	0.25	1	2	2020
Lecture Notes *in* Electrical Engineering	1	1	0.5	2	1	2022
Metaphilosophy	1	1	0.14285714	19	1	2017
Proceedings—18th *IEEE/ACIS* International Conference *on* Software Engineering, Artificial Intelligence, Networking *and* Parallel/Distributed Computing, *SNPD* 2017	1	2	0.14285714	4	2	2017
Proceedings—2015 8th Romania Tier 2 Federation: Grid, Cloud *and* High Performance Computing *in* Science, *RO-LCG* 2015	1	1	0.11111111	1	1	2015
Proceedings *of the* Annual Hawaii International Conference *on* System Sciences	1	1	0.33333333	3	2	2021
Regulation *and* Governance	1	1	0.2	20	1	2019
REHABEND	1	1	0.125	1	1	2016
Research Policy	1	1	0.1	52	1	2014
RISTI—Revista Iberica De Sistemas E Tecnologias De Informacao	1	1	0.25	1	1	2020
Studies *in* Systems, Decision *and* Control	1	1	0.33333333	21	1	2021
Technological Forecasting *and* Social Change	1	1	0.11111111	7	1	2015
Transforming Climate Finance *and* Green Investment *with* Blockchains	1	1	0.16666667	1	1	2018
Transylvanian Review *of* Administrative Sciences	1	1	0.5	1	1	2022
Universal Journal *of* Accounting *and* Finance	1	1	0.5	1	1	2022
World Development	1	1	0.25	18	1	2020
WSEAS Transactions *on* Business *and* Economics	1	1	0.5	1	1	2022
WSEAS Transactions *on* Environment *and* Development	1	1	0.33333333	22	1	2021

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