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Bibliometric analysis and visualization of published research in emerging technologies

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Emerging technologies are transforming industries, driving the need for comprehensive research to navigate this rapidly evolving landscape. This study presents a bibliometric analysis of 25,397 articles related to emerging technologies, indexed in the Web of Science database from 2013 to 2024, and analyzed using Biblioshiny within the R environment. While existing studies often focus on specific technologies or limited sub-areas, this research addresses a significant gap by providing a comprehensive overview of the intellectual structure of the entire interdisciplinary field. Our findings reveal that Technological Forecasting and Social Change and Innovation Food Science & Emerging Technologies are leading journals. The journal Innovation Food Science & Emerging Technologies has shown remarkable growth, increasing from 51 articles in 2005 to 3092 in 2024. Liu Y is the most prolific author with 94 articles. Keyword analysis identifies "model" (1455 occurrences), "design" (881 occurrences), and "optimization" (832 occurrences) as the most frequent terms, revealing the importance of these concepts. Electrical & Electronic Engineering (3791 articles) and Environmental Sciences (3663 articles) are the most prevalent subject categories, underscoring the interdisciplinary nature of the research. Despite a greater publication volume in 2022 (2374 articles), average citations per year peaked at 7.04 in 2015. The surge in publications signals a rapidly expanding knowledge base and growing interest in emerging technologies across various sectors. This analysis provides a quantitative overview of publication trends, influential contributors, and key thematic areas within emerging technologies, offering novel insights into the field's overall structure and development, which can benefit researchers and practitioners alike by informing strategic decision-making and resource allocation.

Keywords: *Emerging technologies, bibliometric analysis, Biblioshiny, R-package*

1. Introduction

Emerging technologies (Maleki & Nilforoushan [1]) refer to contemporary advancements and innovations in various fields of technology (Dritsas & Trigka [2]; Coccia and Roshani [3]). These technologies can also include sustainable development of an existing technology (Barbhuiya et al. [4]). The concept of emerging technology has somewhat different meanings in various fields such as media, business, science, and education. Emerging technologies are defined as technologies that are currently under development and are considered to have potentially significant social and economic impacts (Taherdoost [5]).The development of new technologies in digital communications and media has created new issues related to digital reproduction and distribution of legal works (Pedrero-Esteban & Barrios-Rubi [6]). This has led governments to take measures to provide appropriate protection and legal certainty to copyright owners, digital technology companies, the public, and other interested (parties Karapapa & McDonagh [7]). Therefore, the development of emerging technologies has created new challenges (Okwu et al. [8]; Sharareh & Fatemeh [9]) in the legal field that clearly need attention, and governments are seeking to adopt appropriate measures to provide the best protection and legal certainty for various individuals.

Emerging technologies are a controversial topic in scientific research, policy-making (Ansarir & Tabatabaeianh [10]), and research activities (Ulnicane, Knight, Leach, Stahl, & Wanjiku [11]). There is no precise definition of these technologies, and various definitions exist. Some consider them as

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emerging due to innovation and predicted socio-economic impact (Derin Güre et al. [12]). Analysts examine these technologies separately, considering their different technical, social, uncertain, and practical characteristics. Research methods based on big data and high computational power have been employed to identify and analyze the emerging processes in the field of science and technology (Kumar [13]). In the past decade, there has been a significant growth in research and published articles in the field of emerging technologies including artificial intelligence (Bohni Nielsen, Mazzeo Rinaldi, & Petersson [14]), Internet of Things (Theoleyr & Pang [15]), blockchain (Rahman et al. [16]), and robotics (Lampropoulos [17]). Given the rapid advancement of these technologies and their widespread impact in various fields including economy, health, education, etc., this topic is very attractive and important for researchers and industries.

Public transportation, as a vital component of urban infrastructure, is increasingly leveraging emerging technologies to enhance its efficiency and sustainability. In this context, mathematical programming and multi-objective models have become prevalent, particularly in larger cities, for optimizing routes and scheduling within public transit systems. These models aim to reduce costs, travel times, and the number of transfers, thereby enabling the efficient optimization of multimodal public transport networks (Mahmoudi, Saidi, & Emrouznejad [18]). In parallel with these advancements, emerging technologies are transforming various industries. For instance, (Watson et al. [19]) examine the applications of Artificial Intelligence (AI) and Automated Decision-Making (ADM) in Australian healthcare, focusing on areas such as monitoring, data analysis, cloud computing, and robotics. Furthermore, emerging technologies like blockchain and software-defined networking (SDN) are revolutionizing IOT applications by addressing security and operational challenges. SDN, combined with network function virtualization (NFV), ensures efficient operation in cloud ecosystems but faces challenges like third-party dependency. Blockchain offers decentralized and secure data transfer solutions, enhancing the security and efficiency of IoT systems (Islam, Rakshit, & Paul [20]; Rahman et al. [16]). In addition to these technological advancements, the GreenTech revolution is also transforming industries by offering innovative solutions to environmental challenges. GreenTech encompasses technologies and practices aimed at reducing environmental impact, conserving natural resources, and promoting sustainability across industries like energy, transportation, agriculture, and waste management. Despite facing challenges such as technological barriers and societal resistance, GreenTech presents opportunities for innovation and market growth driven by technological advancements and strategic partnerships (Bruce, Vandelanotte, & Gandhi [21]).

The rapid growth of research in emerging technologies has led researchers to seek tools like bibliometric analysis to manage and analyze the vast amount of information available. Bibliometric analysis enables researchers to identify and examine the number of articles and books published in the field of emerging technology, comparing the number of authors, types of articles, and citation rates over time (Ishmuradova et al.,[22]; Pramono and Nurhakim,[23]). The primary objective of this research is to extract trend patterns from the bibliography of articles published over the past decade and identify researchers, innovations, and topics that have garnered the most attention using bibliometric analysis tools.

However, despite the expanding literature on emerging technologies and the application of bibliometric methods, a significant research gap remains: few studies have comprehensively mapped the overall intellectual structure of this interdisciplinary field, identifying key research clusters and their evolution over time. While existing studies often focus on specific technologies or limited sub-areas, there is a lack of a comprehensive and longitudinal perspective that reveals the main topics, influential factors, and knowledge flows shaping the broader landscape of emerging technologies. This is what this study aims to address.

The goal of this study is to fill this gap by providing a comprehensive bibliometric analysis of 25,397 articles published between 2013 and 2024, extracted from the Web of Science database. Using the Biblioshiny software, this research identifies influential authors, leading journals, organizations, and countries active in this field. Furthermore, it employs advanced bibliometric techniques to map networks of author collaboration, thematic trends, citation networks, and key research clusters. A notable innovation of this work lies in its comprehensive approach, longitudinal perspective over a ten-year period, and integration of multiple bibliometric techniques to provide a nuanced understanding of the intellectual structure and development of the field of emerging technologies. By identifying key

research clusters and their evolution, this study provides valuable insights for researchers, policymakers, and practitioners seeking to navigate and contribute to this rapidly evolving field.

2. Methodology

This study utilizes bibliometric analysis, a widely recognized scientific research method that employs statistical techniques to analyze publications, particularly in scientific fields. This approach is valuable for mapping the structure of a field, identifying influential works and authors, and tracking the evolution of research themes over time. Specifically, bibliometric analysis examines relationships between authors and sources using quantitative methods such as scatter distribution and citation analysis (Moradi & Meybodi, [24]). The core objective is to conduct quantitative analysis on diverse resources, including books, articles, conference proceedings, and other scholarly content (Homayounfar, Fadaei, Gheibdoust, & Rezaee Kelidbari ,[25]). The methodology integrates two complementary approaches: performance analysis and graphical mapping (Tushar et al., [26]). Performance analysis focuses on evaluating the productivity and impact of research entities, such as authors, journals, and institutions, through metrics like publication counts and citation rates. Graphical mapping, on the other hand, visualizes the relationships between these entities using network analysis and other visualization techniques to reveal patterns of collaboration, knowledge flow, and thematic clustering.

The bibliographic data for this study was sourced from the Web of Science database, a leading resource for bibliometric and scient metric research across various disciplines. Web of Science was chosen for its comprehensive coverage of scholarly literature and its robust indexing of citations, which are crucial for bibliometric analysis. Following standard protocol, we searched for the keyword "emerging technology" within the titles, abstracts, and keywords of documents. The search strategy was designed to capture a broad range of publications relevant to emerging technologies, while also ensuring the precision of the results by focusing on the most relevant fields (title, abstract, keywords). The search was limited to articles published between 2013 and 2024 to provide a contemporary view of the field. Furthermore, the document type was restricted to articles written in English to ensure linguistic accessibility and to focus on the core international literature in the field. This systematic process yielded 25,397 documents, which were then downloaded as a Plain Text file for bibliometric analysis.

The analysis was conducted using Biblioshiny within the R programming environment. Biblioshiny is a prominent open-source tool specifically designed for bibliometric analysis, offering a user-friendly interface and a wide range of analytical functionalities (Kumar,[27] ;Kumar & Sahoo, [28]) .We utilized Biblioshiny to perform several key analyses, including:

Descriptive Analysis: To examine publication trends, identify leading authors and journals, and determine the most frequent keywords.

Co-citation Analysis: To identify influential papers and research clusters based on citation patterns.

Co-authorship Analysis: To map collaboration networks and identify key research groups.

Keyword Analysis: To reveal dominant themes and emerging research areas.

Thematic Mapping: To visualize the intellectual structure of the field and identify key research themes and their relationships.

Figure 1 provides a visual representation of the research methodology employed in this study.

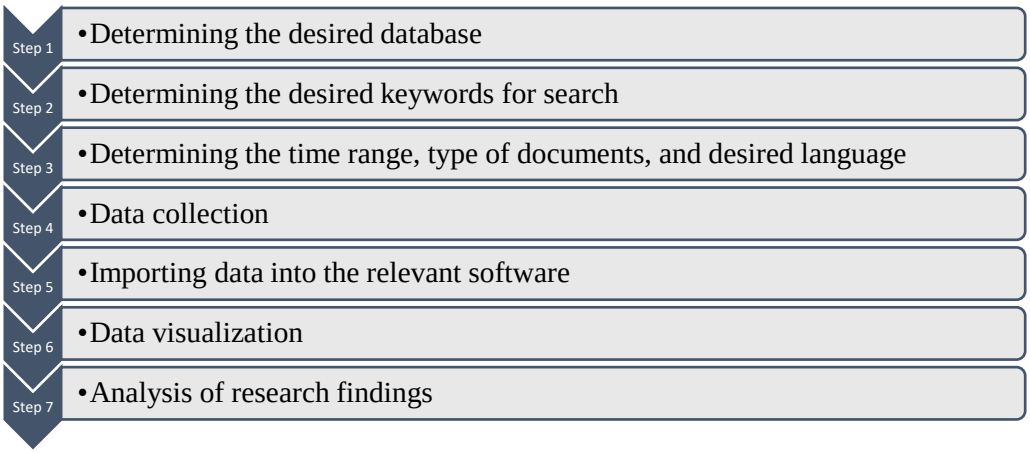

Figure 1. Research steps

3. Research Findings

1.3. Annual Scientific Production

The field of emerging technologies has experienced substantial growth over the past ten years. As illustrated in Figure 2, the number of annual publications has shown a clear upward trend since 2013, indicating the increasing significance of this research area (Seoane-Mato et al., [29]). In 2013, there were 988 articles published, which rose to 1730 in 2019, and further increased to 2783 in 2024. Despite some fluctuations, the overall trend from 2013 to 2024 demonstrates a consistent increase. This notable growth reflects the widespread attention that emerging technologies have garnered from researchers and academics alike.

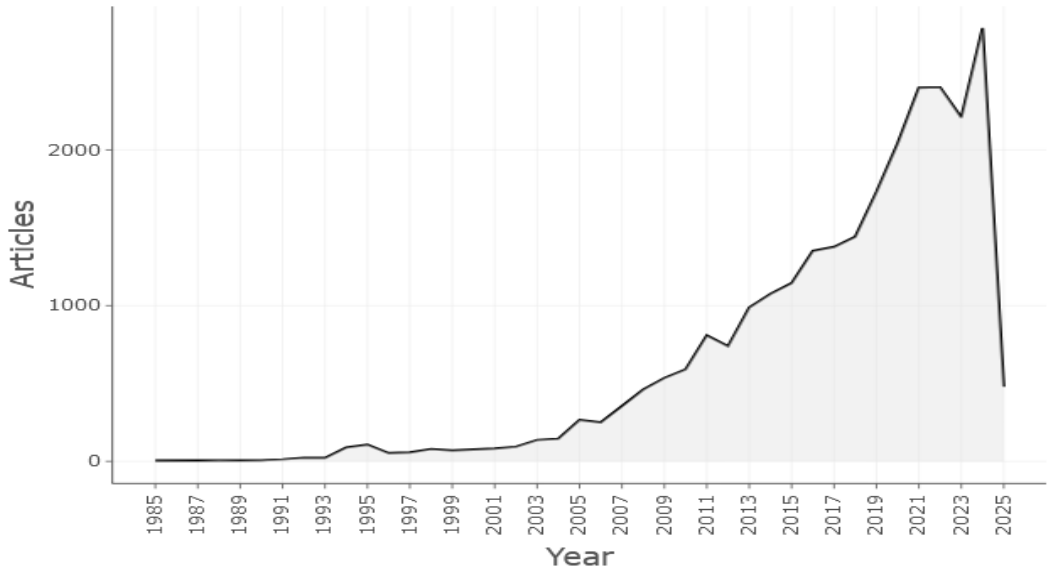

Figure 2. Annual Scientific Production

This surge in publications signals a rapidly expanding knowledge base and growing interest in emerging technologies across various sectors. For managers and business leaders, this trend underscores the urgency to prioritize innovation and investment in emerging technologies to maintain a competitive edge. Organizations should consider allocating resources to R&D, exploring partnerships with research institutions, and fostering a culture of continuous learning to stay abreast of the latest advancements.

2.3. Source Growth

This study examines the trends in journals publishing research related to emerging technologies. Our analysis reveals that this field has experienced substantial growth between 2013 and 2024, with a general upward trend across various journals (Figure 3). For example, the number of articles published in the Innovation Food Science & Emerging Technologies journal has dramatically increased from 51 articles in 2005 to 3092 in 2024. Similarly, the Transportation Research Part C: Emerging Technologies journal has seen a significant rise in publications, growing from 1324 articles in 2016 to 3507 in 2024. Additionally, the Journal of Emerging Technologies in Accounting has demonstrated remarkable growth, increasing from 132 articles in 2008 to 2203 articles so far in 2024.

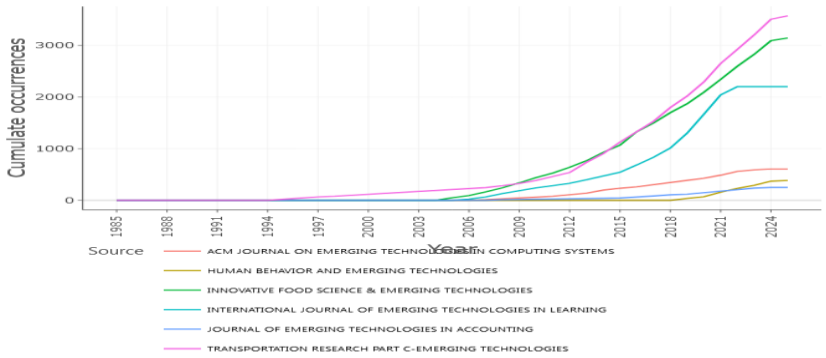

Figure 3. Source dynamics

The growth in publications across various journals (Qazi et al., [30]) underscores the interdisciplinary nature of emerging technologies. Organizations aiming to innovate in this space should cultivate cross-functional collaboration and knowledge sharing to leverage expertise from diverse fields. For instance, a company developing new materials for electric vehicle batteries should not only follow advancements in materials science, but also monitor publications related to transportation, energy storage, and environmental impact assessment. This approach will enable them to better anticipate the broader implications of emerging battery technologies on sustainability, market adoption, and regulatory issues.

3.3. Word Cloud

Word cloud visualization offers a powerful and visually intuitive approach to analyzing textual data within bibliometric studies (Ghorbani Pereira,[31]; Basilio, & Santos,[32]). These clouds represent the frequency of words within a body of text, where the size of each word corresponds to its prevalence or significance. By examining a word cloud, researchers can swiftly pinpoint the most frequently recurring keywords or terms, gaining valuable insights into the primary topics, overarching themes, and key research areas covered in the analyzed literature. The word cloud generated from our analysis (Figure 4) visually represents the terms most frequently employed by authors in articles pertaining to emerging technology. The term "model" clearly dominates, appearing an impressive 1455 times. Closely following is "design," which appears 881 times, solidifying its position as the second most prevalent keyword. "Optimization" ranks third, with 832 occurrences, while "performance" completes the top four, appearing 823 times. These frequent keywords offer a valuable snapshot of the core areas of focus within the field of emerging technologies. To maximize their potential for innovation and maintain a competitive edge, managers should strategically align their R&D initiatives and talent acquisition efforts to cultivate

expertise in these key areas. For instance, a company developing AI-powered solutions could leverage these keywords to inform the development of comprehensive training programs, ensuring that their engineers and data scientists possess a robust foundation in the modeling, design, optimization, and performance evaluation of AI algorithms.

Figure 4. Word cloud

Biblioshiny offers users the ability to customize word clouds by adjusting parameters such as word frequency thresholds, color schemes, and font styles. This flexibility allows researchers to tailor the visualization to their specific analytical needs. Biblioshiny word cloud visualizations can also be applied based on the categorization of topics or research disciplines within the analyzed literature. In this approach, rather than displaying individual words, the word cloud can be customized to represent categorized topics or research disciplines. Each category or discipline is represented by a term, and the size of the term reflects its frequency or importance within the analyzed literature. Researchers can leverage categorized topic word clouds to quickly identify prominent categories in their literature, gaining insights into the distribution and focus of research across different disciplines.

Figure 5 presents the most frequently searched subject areas in the field of Emerging Technologies, which have been used as the primary keywords. Analysis of keyword frequencies reveals that the highest frequencies occurred in the subject categories of transportation science & technology (3772), food science & technology (3625), education & educational research (2775), and so forth.

Figure 5. Frequency of subject categories

Understanding the most frequent subject areas can inform strategic partnerships and market entry decisions. Companies seeking to expand into emerging technology markets should prioritize areas with

high research activity, as this indicates a strong potential for growth and innovation. For instance, a venture capital firm looking to invest in emerging technologies could focus on companies operating in the intersection of transportation, food science, and education, as these areas are receiving significant attention from researchers and may offer promising investment opportunities.

4.3. Most Relevant Authors

Bibliometric analysis is an effective method for identifying key contributors within a research domain (Petermann-Rocha et al., [33]). In the field of emerging technologies, Liu Y and Zhang Y stand out as the most prolific authors, each contributing a substantial 94 articles. Following these leading researchers, Stoyanov D ranks third with 72 articles, and Wang Y comes in fourth with 71 articles.

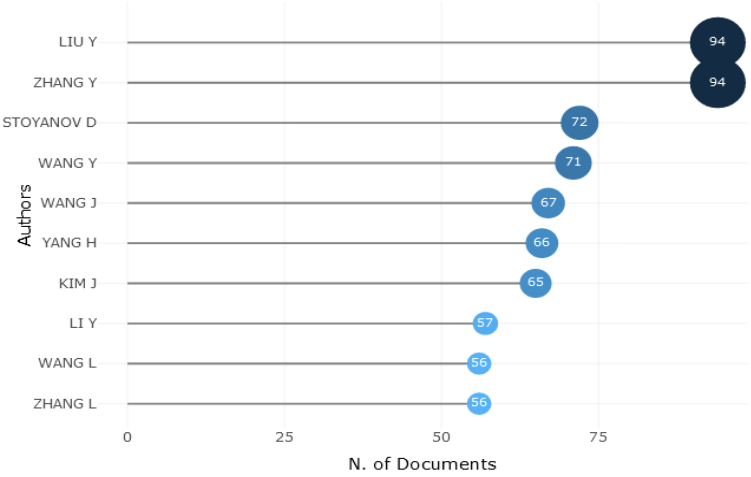

Figure 6. Most Relevant Authors

Identifying and tracking the work of prolific authors can offer valuable insights into emerging trends and potential research collaborations. Managers should consider inviting these authors to speak at industry events, participating in their research studies, or exploring opportunities for joint ventures. This could involve sponsoring research projects, offering internships to their students, or co-authoring publications to enhance their organization's visibility and credibility in the field.

5.3. Authors' Production Over Time

In author analysis, various metrics are used to assess a researcher's scientific output, performance, and impact, including their connections, citations, longitudinal production, adherence to Lotka's law, and overall influence (Huamán-Mendoza,[34]; Matsubae, & Itsubo, [35]). Within the field of emerging technologies, authors are categorized based on their relevance, citation count, and impact. Figure 7 vividly illustrates the most prominent authors in this domain over the study period from 2013 to 2024. The timeline of each author's scientific production is depicted by lines, with the size of the bubble blocks proportional to the number of documents published annually, and the color intensity reflecting the number of citations received that year. As documented in the Web of Science database, Liu Y stands out as a leading author, having published 94 articles between 2013 and 2024, which garnered a substantial number of citations. Notably, in 2018, one of Liu Y's articles received 36 citations, and in 2024, 15 articles collectively earned 19 citations. Following Liu Y, Zhang Y and Anonymous are ranked in subsequent positions.

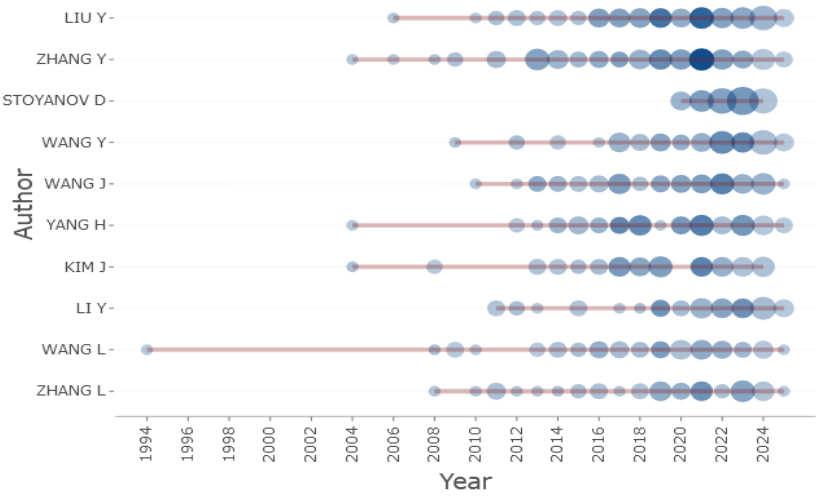

Figure 7. Authors' production over time

By monitoring the longitudinal production and citation impact of key authors, managers can gain a deeper understanding of the evolution of research trends and identify potential breakthroughs. It is crucial to consider the timing and impact of an author's work; for example, if Liu Y's most cited work was around 2018, that can inform managers about the direction that will be impactful in coming years. Furthermore, this information can be valuable in assessing the potential of new hires or collaborators. For instance, if an organization is looking to expand into a new area of emerging technology, it may be beneficial to recruit researchers who have a proven track record of high-impact publications in that specific domain.

6.3. Three-field plot

The three-field plot (Figure 8) provides a visual representation of the interrelationships between journals, authors, and keywords within the emerging technologies literature (Gu et al.,[36]; Pangriya & Pandey, [37]). This diagram comprises three interconnected sections, with gray lines illustrating the connections between these elements. The size of each rectangle within a section corresponds to the number of articles associated with that element. The leftmost section lists journal names (Qiao, Xie, Li, Cao, & Zhao, [38]), indexing the top ten journals with the highest publication volume in emerging technologies. Scientometrics stands out as the leading journal, represented by a distinct rectangle, followed by Technological Forecasting and Social Change. The plot also reveals connections between these journals and prominent authors, such as Liu Y's association with Technological Forecasting and Social Change. This journal is, in turn, linked to multiple authors, including Kim, Zhang, and Porter.

The middle section presents a list of authors, each linked to frequently used keywords on the right. The top 20 authors, including Porter and Liu Y (represented by the largest rectangles), are featured in this section. Finally, the rightmost section displays keywords related to emerging technologies, ranked by frequency of appearance in the literature. Each keyword is associated with authors who have published extensively on that topic. This section lists the top 20 keywords, with "emerging technologies" being the most prevalent, followed by "emerging technology" and "ultrasound."

Visualizing the intricate relationships among authors can enable managers to strategically allocate available resources to facilitate collaboration with leading experts. By fostering appropriate collaborations, organizations can optimize their approach and enhance their potential for success.

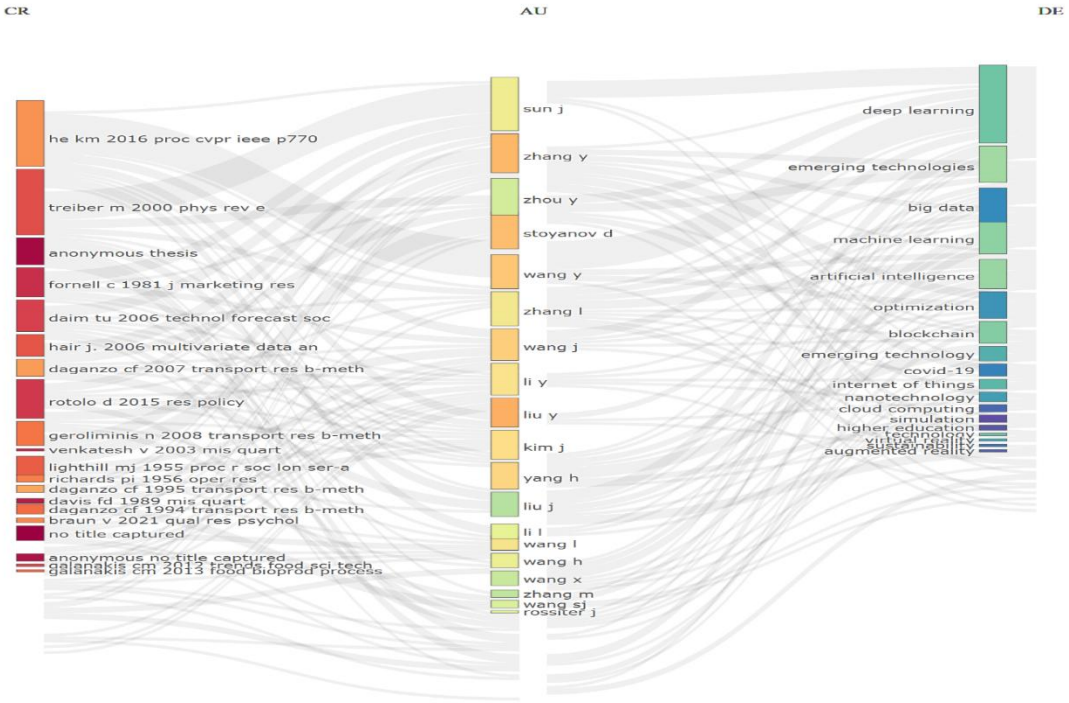

Figure 8. Three-field plot

7.3. Average Citations per Year

The average number of citations per year is a valuable metric for assessing the annual impact of a journal or author (Hassan & Duarte,[39]; Karabay, [40]). This index is calculated by dividing the total number of citations by the number of years the author or journal has published articles (Vaishya, [41]). It enables researchers to evaluate the impact of each article while considering its age (Wei et al., 2023). Additionally, this index accounts for the duration of activity of a journal or author and can serve as an alternative to the h-index (Figure 9).

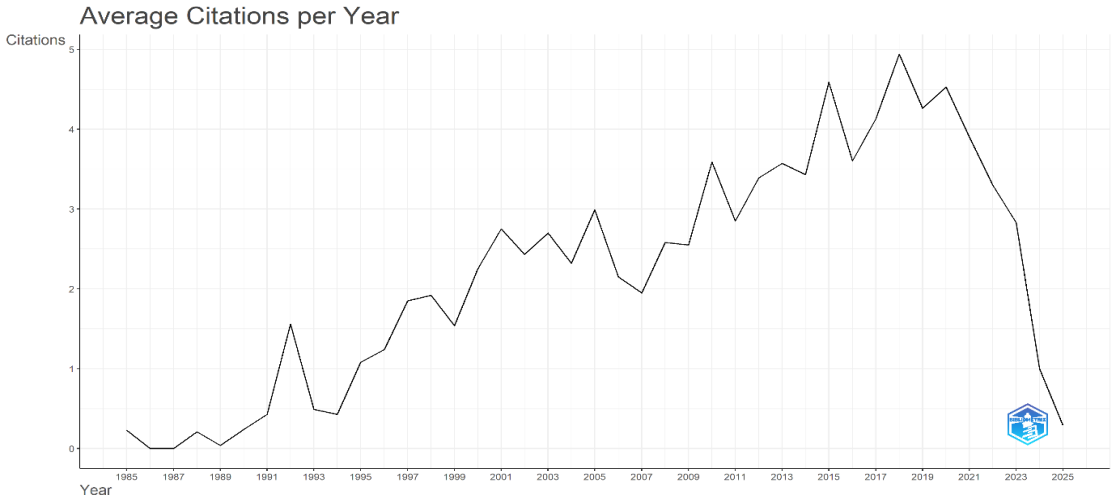

Figure 9. Average Citation per year

Sorting the citation column by year allows authors or journals to examine the most influential publications. This index is calculated by considering the total number of citations and the number of years an author or journal has published articles, taking into account the duration of activity of a journal or author. As such, it can be used as an alternative to the h-index. Table 1 presents the average citation per year. The results show that in 2015, with 1101 articles, the citation rate was 4.59. In 2021, with 2320 articles, the annual citation rate was 3.90. However, in 2024, with 2641 articles, the citation rate was 5.10, which was higher than in 2015.

Table 1. Annual Average Citation

Year	Number	Average Annual Citations	Citable Years
2015	1101	4.59	11
2016	1303	3.60	10
2017	1321	4.13	9
2018	1390	4.94	8
2019	1657	4.26	7
2020	1949	4.53	6
2021	2320	3.90	5
2022	2310	3.30	4
2023	2110	2.83	3
2024	2641	5.1	1

Monitoring average citation rates gives managers insight into the long-term impact of specific areas of research. Declining rates may indicate that a technology is losing momentum, and it can guide the decision to allocate investment.

8.3. Tree Map

A tree map diagram offers an alternative method for visualizing hierarchical structures using nested rectangular sections, while also displaying the values associated with each category through the size of the area corresponding to that category (Kumar & Sahoo, [28]). In tree map visualization, hierarchical information is presented using nested rectangles that represent internal areas. Each rectangle corresponds to a specific category, such as a journal, author, or keyword. The size of the rectangle is proportional to the importance or frequency of the category within the analyzed literature (Sumbul ,[42]).

Figure 10. Tree Map

If no specific quantity is assigned to a subset, its area is divided equally among other subsets within its main group. Researchers can analyze relationships between different categories by examining the tree map. By analyzing the size and position of rectangles, they can identify patterns, clusters, or distinct points, which helps in understanding the distribution and connections within the literature collection. Tree maps can be created for different data subsets to facilitate comparative analysis. By comparing the size and order of rectangles between datasets, researchers can quickly gain insights into changes in research focus, collaboration patterns, or publication trends across different times or groups. The tree map presented in Figure 10 shows a combination of potential keywords. The keyword "Model" with 1417 repetitions accounts for 7% of the keywords. Another frequently used keyword is "design," which also accounts for 4% of the keywords. Additionally, the keywords "optimization" with 806 repetitions is the least used keywords. In order to have an understanding, a company can analyze the tree map in order to improve different sectors of their firm.

9.3. Lotka's law

Lotka's law, also known as the 'inverse square law of scientific productivity,' posits that the number of authors publishing a certain number of articles is inversely proportional to that number raised to a power (Wan Liah, [43]). Introduced by Alfred J. Lotka, (Amarathunga,[44]) an American mathematician and statistician, this law suggests that a larger number of authors in a particular field produce fewer articles, while a smaller number of authors produce more. According to Lotka's law, approximately 79.6% of authors contribute with one article, 11.4% with two articles, 3% with three articles, and 1% with four articles. This indicates that most authors have contributed with only a single article in their field. The relationship between Lotka's law and the number of articles published by authors is illustrated in Figure 11. Given that most authors contribute only one article, companies should focus on identifying valuable collaborators to enhance productivity. Innovative firms would benefit from concentrating on the smaller percentage of authors who are prolific, as they are likely to drive significant advancements in their field.

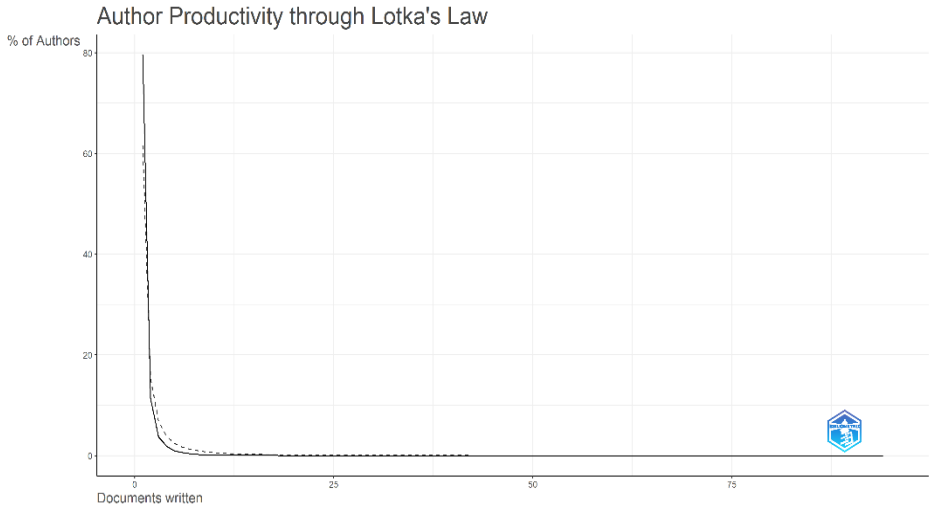

Figure 10. Lotka's Law

10.3. Corresponding Author's Country and Publications

Table 2 presents a list of authors corresponding to each country, along with their number of publications. The table analyzes the number of single-country publications (SCP), multi-country publications (MCP), and the ratio of multi-country publications (MCP-Ratio) (Hashimoto et al.[45] Nath, Thomson, Baker, & Jamieson, [46]). The United States leads with a total of 5363 articles, of which 4422 were single-country and 941 were multi-country publications, resulting in an MCP ratio of 0.175. This indicates that most emerging technology research publications in the US were authored domestically. China ranks second, with a total of 3660 articles, comprising 2527 single-country and 1133 multi-country publications, yielding an MCP ratio of 0.31. In contrast, the United Kingdom shows a notable level of international collaboration, with 1099 single-country articles and 703 multi-country collaborations. A high MCP ratio suggests a greater degree of collaboration between a country and other nations.

Table 2. Country of Corresponding Author

Country	Articles	Articles %	SCP	MCP
USA	5363	21.1	4422	941
CHINA	3660	14.4	2527	1133

UNITED KINGDOM	1802	7.1	1099	703
ITALY	1098	4.3	726	372
SPAIN	964	3.8	671	293
INDIA	934	3.7	753	181
GERMANY	842	3.3	514	328
AUSTRALIA	759	3	480	279
CANADA	673	2.6	472	201
FRANCE	664	2.6	397	267

Figure 11 shows a graphical representation of the corresponding author's country and the number of publications by the respective authors (Hezam, Fu, Zhang, & Li, [47]). The most innovative companies should always seek researchers from other countries to obtain more diverse research and increase the company's overall innovation.

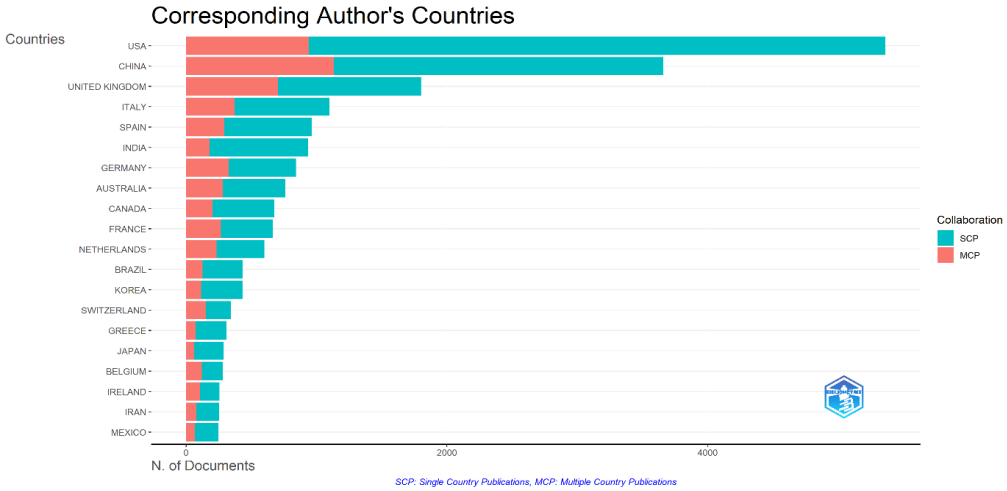

Figure 11. corresponding author's country

1۱.3. Thematic Map

A thematic map in bibliometrics refers to a graphical representation that shows the distribution of a specific thematic variable across different regions or categories. In the context of bibliometric analysis, a thematic map can be used to visualize geographical patterns or classification of scientific articles, citations, or other related bibliographic data (Abdelwahab, Taha, & Mohan, [48]; Kaushal, Kaurav, Jha, Ghalawat, & Kaswan, [49]). In Figure 12, the coordinate axis is divided into four topological areas based on density and centrality. This result was obtained through a semi-automatic algorithm by observing the titles of all sources analyzed in this study and additional relevant keywords (other than author keywords) to record deeper changes (Afonso, [50]). The upper right quadrant includes driving or motor themes, which are characterized by high density and centrality and, given their importance, should be further developed for future research. These topics include innovation, science, and knowledge.

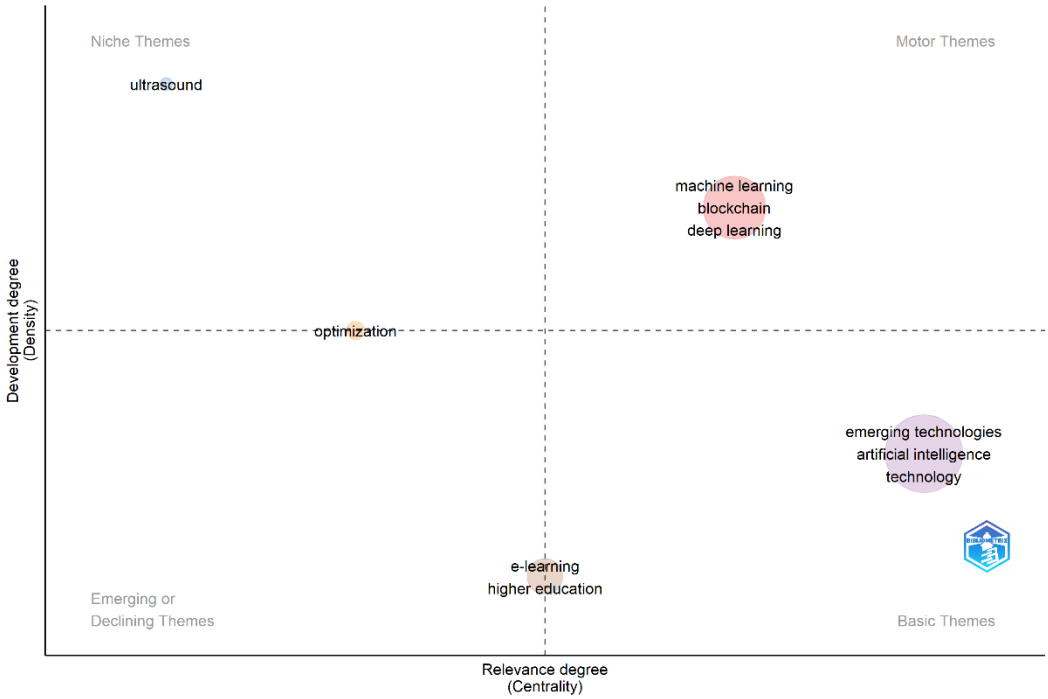

Figure 12. Thematic map

The upper left quadrant shows specific and less-displayed topics characterized by high density but low centrality. These topics, including extraction, recovery, and by-product, are experiencing rapid growth in the field of emerging technologies. The lower left quadrant includes topics that have been used but have experienced a downward trend, indicated by low centrality and density. This area includes water, nanoparticles, and fabrication. Finally, the lower right quadrant contains fundamental topics shown with high centrality but low density. These topics are important for research as general subjects and include design, performance, and system. Thematic maps allow for managers to improve their strategic decision making. By investing in driving themes, they are leading to significant advancements. Exploring niche areas allows for untapped potential.

12.3 . Thematic Evolution

Thematic evolution is a crucial feature in the Bibliometrix tool, allowing users to track the development of themes over time in scientometric datasets or journals (Abdelwahab et al. [48]; Umar, Lazi, Hassan, Hashim, & Zhang, [51]). This capability enables researchers to examine the progression of innovations and the trend of topic evolution over time. It involves analyzing key characteristics of topics to categorize them across different years (Singh, [52]). For instance, thematic evolution analysis can help identify successful topics and current trends in science, as well as how they evolve over time. In summary, thematic evolution in Bibliometrix facilitates the examination of thematic developments over time and the analysis of patterns and trends in scientometric datasets. In this study, thematic evolution was examined across two time periods: 1985-2019 and 2020-2025. Figure 13 illustrates the evolution of research topics, clusters, or themes during these two periods. Despite the evolution and diversity of research topics over time, the core themes remained consistent. The clusters of E-learning, Technology, Optimization, and Emerging Technologies were the four top research topics throughout the study period. Since certain trends persist, this can benefit organizations by informing strategic decisions that align with enduring themes. Managers should remain vigilant in strategizing around new trends and themes to maintain relevance.

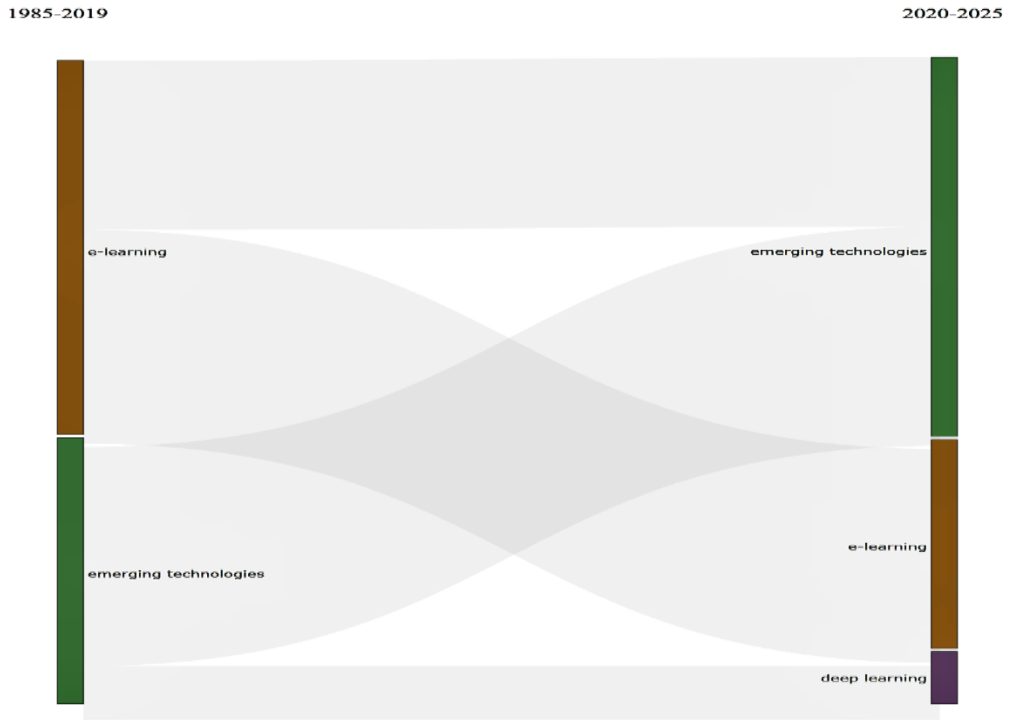

Figure 13. Thematic Evolution

13.3. Trend Topics

Figure 14 presents an analysis of research related to emerging technologies over a specific time period (Veres, Tănase, Bacos, & Kardos, [53]). The pattern of word usage reveals that words positioned higher and further to the right are more frequently used in research (Apriandi et al., [54]). In 2024, the topics "AI," "transportation," and "acceptance model" were the most frequently employed. By 2023, topics such as "artificial intelligence," "vehicle-routing problem," and "augmented reality" gained widespread usage. The analysis also highlights when each topic gained prominence. For instance, challenges have consistently been a major focus from 2020 to 2023, while big data reached its peak usage in 2022. Artificial intelligence saw a significant rise in interest, particularly from 2022 to 2024.

Trend Topics analysis offers a valuable tool for firms to understand the evolution of key topics within emerging technologies (Huamán-Mendoza et al., [34]). By examining how the prominence of different keywords shifts over time, managers can gain insights into which areas are gaining traction and which may be losing importance. For instance, the rise of "artificial intelligence" and "acceptance model" in recent years indicates a growing focus on these areas, which may justify increased investment or strategic attention. Conversely, a decline in the usage of other terms could signal a need to reassess their relevance to the firm's overall strategy. Ultimately, by closely monitoring these thematic trends, companies can make more informed decisions about resource allocation, R&D priorities, and potential new business opportunities, thereby maintaining a competitive edge in the dynamic landscape of emerging technologies.

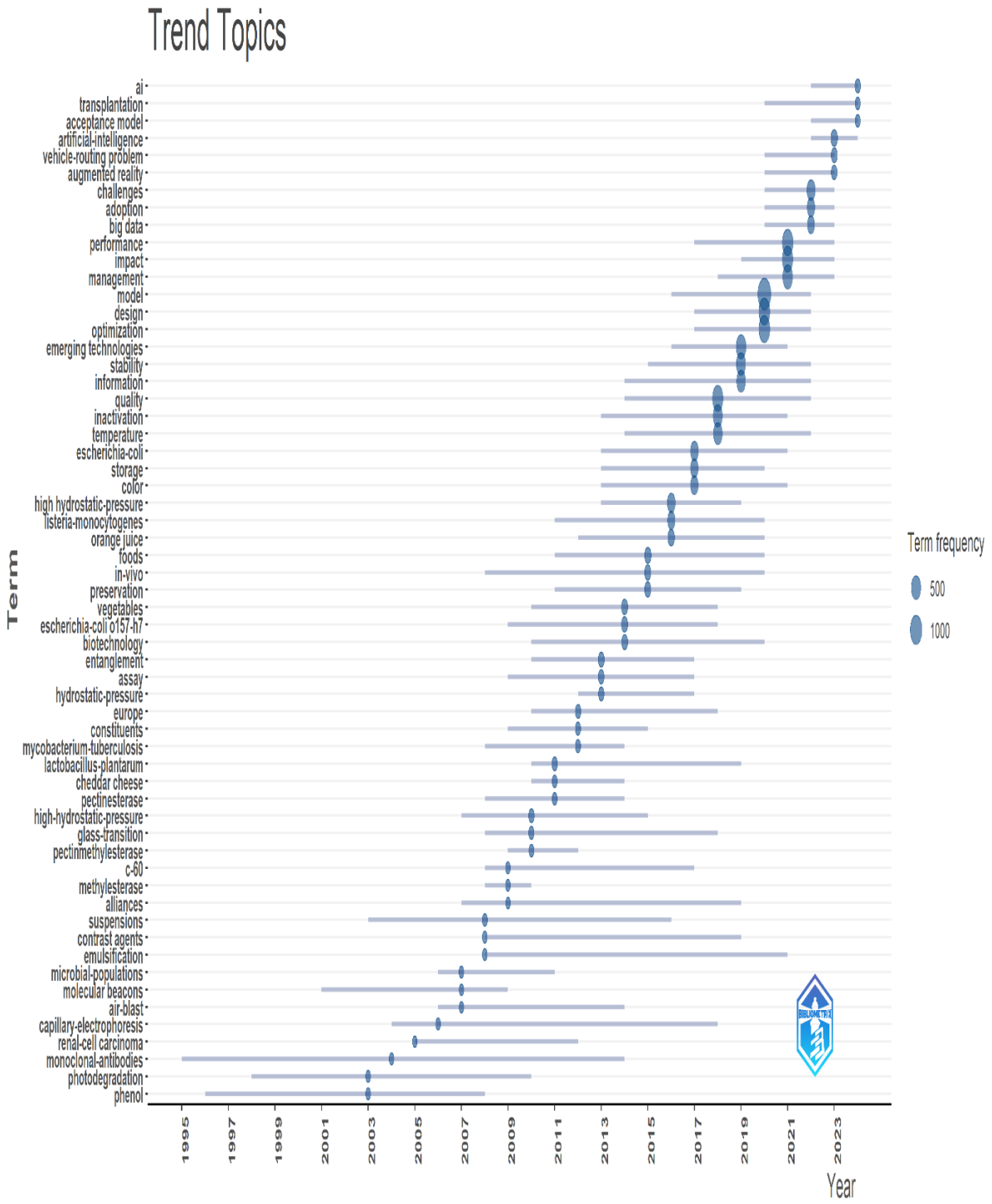

Figure 14. Trend Topics

14.3. Analysis of Conceptual Structure

This section leverages the conceptual structure function embedded in Bibliometrix to explore the conceptual landscape of research (Mahdavinasab & Haseli, [55]) in emerging technologies. Utilizing Biblioshiny software, which corresponds to the Multiple Correspondence Analysis (MCA) technique, we have identified the conceptual structure of the subject and applied K-means clustering to group

documents with shared concepts. The MCA technique serves as an exploratory multivariate method for both graphical and numerical analysis of multivariate categorical data. Its primary purpose is to examine the interdependence among a set of classified variables and uncover new hidden variables, or factors. The results are interpreted based on the relative position of points and their distribution along the dimensions, where words with similar distributions are depicted closer together. Notably, new insights have emerged from the factor analysis of keywords. In this study, we used the 50 most frequent keywords in the emerging technologies literature to identify seven categories of documents that relate similar concepts. These categories are plotted and displayed in Figure 15.

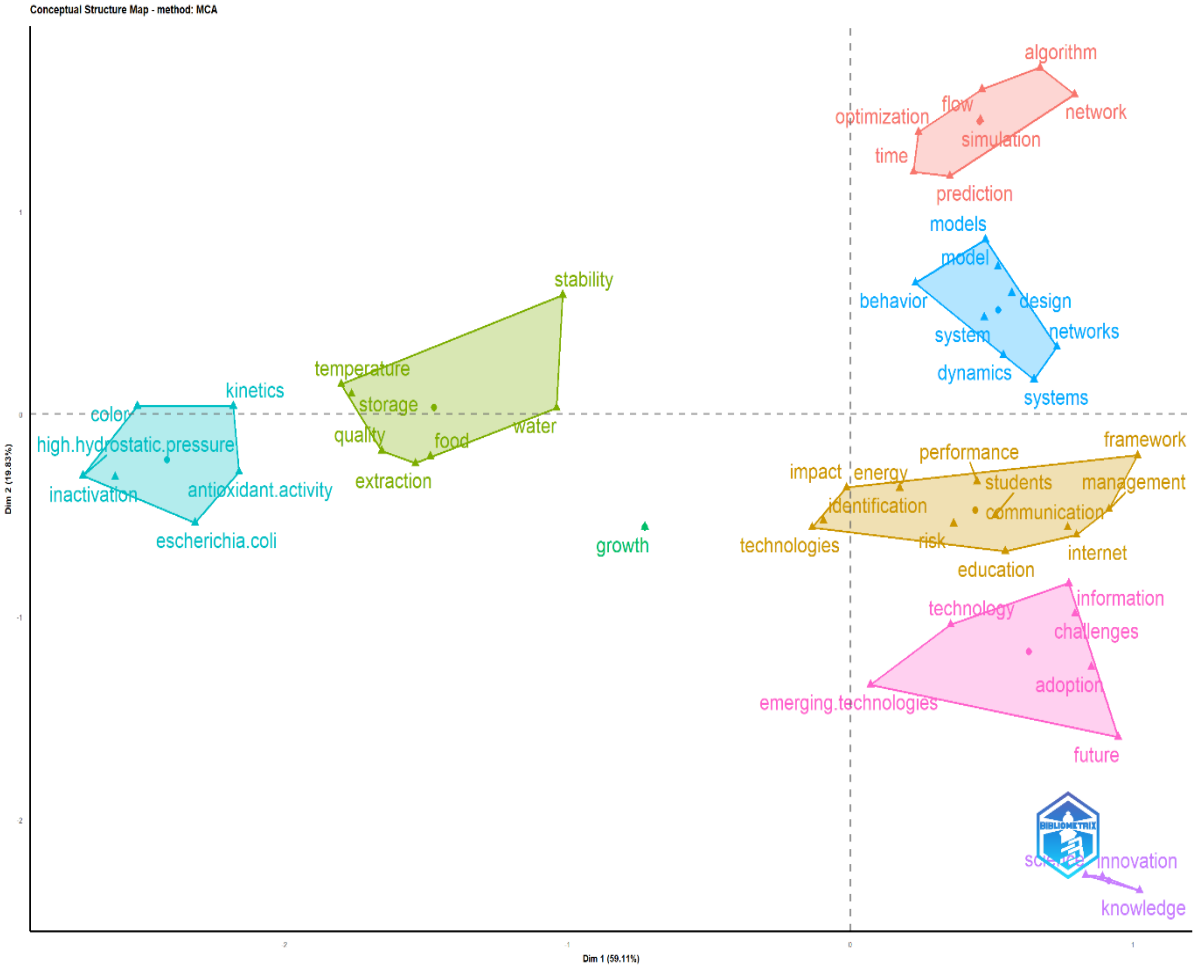

Figure 15. Conceptual Structure Map

Analyzing the conceptual structure of the field gives a firm the ability to identify both well-established and emerging areas of research. By understanding the relationships between key concepts and themes, managers can better direct resources toward promising areas for innovation. This analysis can also highlight gaps in the existing literature, suggesting potential new avenues for research and development. A proactive company will use this information to inform its long-term strategic goals and improve innovation. With this information, they can also seek to improve the areas that are weak, and focus on the strong points that will maintain success.

15.3. Countries' Collaboration World Map

The Collaboration World Map is a powerful visualization tool within the bibliometrix package, designed to illustrate the geographical distribution of collaborations between authors or institutions on a global scale (Zheng et al., [56]). This tool provides a visual representation of collaboration networks, allowing researchers to analyze international collaborations between countries, institutions, or authors (Hassan & Duarte, [39]. The map displays nodes representing countries or institutions and links indicating collaborations, with the thickness of these links signifying the strength or frequency of collaborations (Zheng et al., [56]). Analyzing the Collaboration World Map enables researchers to understand patterns of international collaboration within specific research fields or disciplines. It also helps identify key players, centers of collaboration, and potential areas for future collaboration. Overall, the Collaboration World Map in bibliometrix aids researchers in visualizing and understanding a global perspective of collaborations in scientific research. International collaboration in emerging technologies is extensive and demonstrates the presence of robust international research networks. Countries with a higher number of publications tend to have a higher level of collaboration, assisting each other in developing valuable scientific research results. The United States emerges as a significant hub for collaboration in emerging technologies, with the most collaborations with China (746), the United Kingdom (371), Canada (225), and Germany (217), highlighting its central role in international collaboration networks. China also has significant collaborations with the United Kingdom (278) and Australia (169), reflecting its efforts to expand international partnerships. International collaboration in emerging technologies is crucial for the scientific and economic advancement of countries. These collaborations help developing countries like China benefit from the experiences and advanced technologies of developed nations. For instance, the collaboration between the United States and China in emerging technologies such as artificial intelligence and renewable energy has accelerated the development of these technologies.

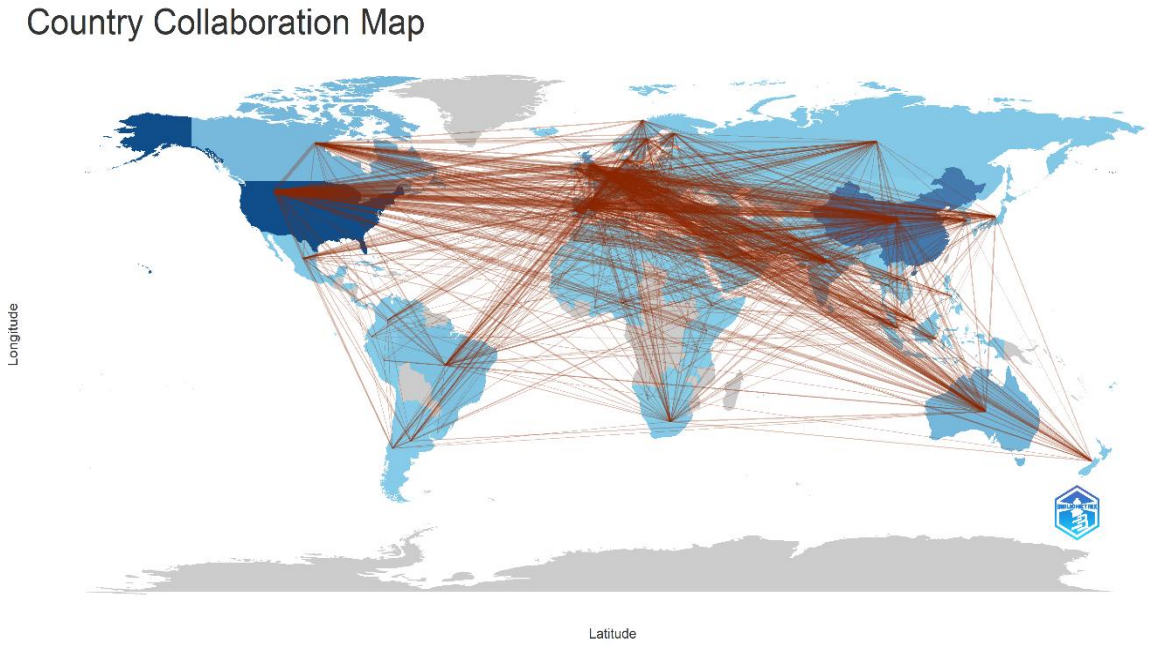

Figure 16. countries' Collaboration World Map

Figure 16 clearly illustrates the extent of international collaboration in emerging technologies. The presence of international research networks, depicted in blue, underscores the importance of these collaborations in scientific progress. These networks serve as bridges for scientific exchange and the development of research collaborations, enabling countries to advance in various emerging technology fields. The strengths of international collaboration in emerging technologies include helping developing countries leverage resources and experiences from developed nations, thereby facilitating faster development. However, some countries may not fully benefit from these opportunities due to limited

access to resources or lack of experience in international collaborations. Ultimately, international collaboration in emerging technologies is a global phenomenon that contributes to the scientific and economic progress of countries and offers new opportunities for developing nations to advance.

For firms seeking to amplify their innovation efforts, the Collaboration World Map serves as a strategic compass, revealing potential partnerships across the globe. By analyzing the map, organizations can identify countries and institutions with strong research activity in areas aligned with their own strategic priorities. Establishing collaborations with these international entities can provide access to new knowledge, diverse perspectives, and complementary resources, ultimately accelerating the pace of innovation and enhancing the firm's competitive advantage in the global landscape of emerging technologies. This strategic approach not only fosters a collaborative environment but also ensures that companies remain at the forefront of technological advancements, leveraging global expertise to drive growth and innovation.

4. Conclusion

This study provides a comprehensive bibliometric analysis of the research landscape in emerging technologies, leveraging the power of biblioshiny within the R-Package to examine a vast dataset of 25,397 journal articles indexed in the Web of Science database. Spanning the period from 2013 to 2024, our analysis offers a unique and data-driven perspective on the evolution, key trends, and influential actors shaping this dynamic and rapidly expanding field. Emerging technologies, as we have demonstrated, are not merely academic curiosities; they are powerful drivers of societal progress, economic growth, and transformative change across a multitude of industries. From healthcare to transportation, from manufacturing to environmental sustainability, these technologies are reshaping the world around us at an accelerating pace. Understanding their trajectory, their key players, and their underlying themes is therefore of paramount importance for researchers, policymakers, and business leaders alike. Our bibliometric analysis has yielded a number of significant insights. The exponential growth in annual scientific production, as illustrated in Figure 2, underscores the increasing attention and investment being directed towards emerging technologies. This surge in publications signals a rapidly expanding knowledge base and growing interest across various sectors. The identification of leading journals, such as *Innovation Food Science & Emerging Technologies* and *Transportation Research Part C-Emerging Technologies*, provides valuable guidance for researchers seeking to disseminate their work and for organizations seeking to stay abreast of the latest breakthroughs. The word cloud visualization offers a compelling snapshot of the core focus areas within emerging technologies. The prominence of keywords such as "model," "design," "optimization," and "performance" highlights the importance of rigorous methodologies, data-driven approaches, and a relentless pursuit of improved outcomes. These are not merely buzzwords; they represent the fundamental building blocks of successful innovation in the field of emerging technologies.

Furthermore, our analysis of source growth reveals the interdisciplinary nature of emerging technologies. As research publications expand across a diverse range of journals, it becomes increasingly clear that innovation in this space requires cross-functional collaboration and knowledge sharing. Organizations that silo their expertise and fail to integrate insights from different fields risk falling behind in the race to develop and deploy impactful emerging technologies. Finally, our exploration of subject areas reveals the breadth and depth of research activity in emerging technologies. From Electrical and Electronic Engineering to Environmental Sciences, from Computer Science Information Systems to Materials Science, these technologies are permeating virtually every domain of scientific inquiry and technological development.

Emerging technologies present both opportunities and challenges for organizations. Here are some key managerial implications:

1. **Strategic Alignment with Emerging Technologies:**

- Integration into Business Strategy: Emerging technologies are no longer just a supporting element; they are now integral to business strategy. Managers should ensure that their technology investments align with overall business goals and drive innovation.
- Role in Transformation: Emerging technologies can catalyze organizational transformation by creating new business capabilities. Approximately 20% of technology budgets are now dedicated to developing these capabilities, highlighting their strategic importance.

2. Adaptation and Agility:

- Embracing Change: The rapid pace of technological change demands that organizations be agile and adaptable. Managers must foster a culture that encourages continuous learning and innovation.
- Risk Management: While emerging technologies offer opportunities, they also introduce new risks. Managers should develop strategies to mitigate these risks while maximizing benefits.

3. Talent Management and Development:

- Upskilling and Reskilling: As emerging technologies evolve, there is a growing need for employees with relevant skills. Managers should invest in training programs to ensure their workforce remains relevant.
- Leadership Roles: The integration of emerging technologies often requires new roles and responsibilities within organizations. Managers should be prepared to adapt organizational structures and talent management strategies accordingly.

4. Partnerships and Collaborations:

- External Partnerships: No organization can afford to go it alone in the world of emerging technologies. Managers should seek partnerships with research institutions, industry peers, and government agencies to leverage external expertise and resources.
- Cross-Functional Collaboration: Emerging technologies often require a holistic approach, integrating expertise from various disciplines. Managers should foster cross-functional collaboration to ensure successful innovation.

5. Focus on Impactful Outcomes:

- Solving Real-World Problems: Instead of getting caught up in the hype surrounding emerging technologies, managers should focus on developing solutions that address real-world problems and deliver measurable benefits to society.
- Adaptability: Be prepared to adapt strategies as the technology landscape evolves, ensuring that investments remain aligned with organizational goals and societal needs.

While this study provides valuable insights into the landscape of emerging technologies, several avenues for future research warrant consideration:

Qualitative Studies: Conduct in-depth qualitative studies to explore the specific challenges and opportunities organizations face when adopting and implementing emerging technologies.

Longitudinal Analysis: Perform longitudinal studies to examine the long-term impact of emerging technologies on industries, economies, and societies.

Comparative Analysis: Undertake comparative analyses of emerging technology adoption across different countries and regions to identify best practices and inform policy decisions.

Ethical Implications: Investigate the ethical implications of emerging technologies, including issues related to privacy, security, and social equity.

Interdisciplinary Research: Encourage interdisciplinary research collaborations to address the complex challenges and opportunities presented by emerging technologies from multiple perspectives.

Additionally, future research could explore emerging technologies such as biofeedback for post-stroke rehabilitation, tunable liquid lenses, and cybersecurity in operations management. The integration of emerging technologies like AI, blockchain, and 5G in various sectors, including education and healthcare, also presents significant opportunities for investigation. Furthermore, advancements in gene editing, brain-computer interfaces, and quantum computing are poised to revolutionize industries and societal structures, offering fertile ground for future studies.

By understanding these implications and acting on them, managers can navigate the complex landscape of emerging technologies more effectively, driving innovation and ensuring their organizations remain competitive. This bibliometric analysis provides a valuable roadmap for making informed decisions, fostering innovation, and unlocking the transformative potential of emerging technologies to create a better future. The suggestions for future research highlight the need for continued exploration and understanding of this critical field.

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