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Review Article

Mapping the Scientific Research of Artificial Neural Networks (ANN) in Business Sciences: A Bibliometric Analysis and Future Research Avenues

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ABSTRACT

Artificial Neural Networks (ANNs) have emerged as important analytical tools in business research, with applications across accounting, finance, marketing, human resource management, entrepreneurship, and corporate social responsibility. However, previous studies have not provided an integrated mapping of ANN applications across these six major business domains. This study addresses this gap through a bibliometric analysis of 168 Scopus-indexed documents published between 2007 and 2025. Using Bibliometrix, Biblioshiny, and VOSviewer, the study examines publication trends, research performance, and intellectual structures. The dataset includes 145 sources and 479 authors, showing an annual growth rate of 16.45%. Results reveal eight thematic clusters, with commerce and finance and decision-support research identified as key motor themes. Co-citation analysis highlights three intellectual communities: technical ANN, behavioral management, and SEM-ANN hybrid research. The study provides an evidence-based overview of ANN evolution, structure, and future research directions in business sciences.

Keywords: Artificial neural networks, Bibliometric analysis, Business sciences, Performance analysis, Science mapping, SEM-ANN hybrid.

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INTRODUCTION

Artificial Neural Networks (ANNs) have been extensively used in business research over the past three decades, earning recognition as an influential analytical method across multiple application domains (Tkáč and Verner, 2016). Inspired by how biological neural systems work, ANNs can identify complex patterns within large-scale datasets and often predict results more accurately than traditional statistical methods (West *et al.*, 1997). These features have rendered them attractive to business researchers seeking more robust analytical tools to understand complex organizational, financial, and market phenomena (Bahrammirzaee, 2010; Tkáč and Verner, 2016). Starting with financial forecasting and credit risk assessment (Trippi and Turban, 1992), ANNs have been used increasingly across many business areas, including accounting (Coakley and Brown, 2000), marketing analysis (Wilson and Bettis-Outland, 2020), human resource management (Sakib *et al.*, 2025), entrepreneurship (Prakhar *et al.*, 2025), and corporate social responsibility (Binh, 2024). This expansion accelerated markedly from the late 2010s onward, reflecting broader trends in ANN adoption across scientific disciplines (Abiodun *et al.*, 2018).

This growing interest has created a substantial and growing body of literature that describes, evaluates, and improves the use of ANNs in business. Bahrammirzaee (2010) offers an important review of artificial intelligence methods in financial markets, showing how neural networks, expert systems, and combined models effectively deal with complex and changing financial aspects. Tkáč & Verner (2016) provide a detailed overview of neural network uses in business from 1994 to 2015, based on 412 studies. They demonstrate that ANNs are mainly used to predict financial problems, forecast stock prices, and support decision-making, focusing especially on classification tasks and the growing use of hybrid models.

Studies focused on specific areas have further improved our understanding of how ANNs work in particular business fields. Saheb *et al.* (2023) advanced knowledge of neural network-based credit risk modeling in commercial banking. Praveen Kumar and Suguna (2020) argued that dynamic ANN methods are better for sentiment analysis and predicting customer behavior in retail Khtou *et al.* (2024) expanded ANN uses into sustainable supply chain management, giving practical advice for implementation. On a larger level, exploratory studies such as (Elmsili and Outtaj,

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2018) analyzed over 1,100 ANN-related papers using Latent Dirichlet allocation, and bibliometric studies like (Perannagari and Gupta, 2022) mapped ANN research in business, traced its development and called for ongoing monitoring of its fast-changing areas. Most recently, Baysal *et al.* (2023) used VOSviewer to analyze 545 Web of Science articles, providing broad views on the field's main topics and geographic spread.

Together, these contributions have greatly improved the academic community's understanding of ANN uses in business and have provided essential groundwork for this study. However, the fast-changing nature of this research area indicates that regularly updated mappings are not only useful but necessary to capture developments that post-date earlier reviews. Yet the existing literature has yet to examine accounting, marketing, finance, entrepreneurship, human resource management, and corporate social responsibility within a single unified bibliometric framework. Most prior studies focus on a single business sub-discipline or apply only one analytical method, leaving the full intellectual landscape of ANN research across business sciences unmapped.

The present study responds to these opportunities by conducting a thorough bibliometric analysis of ANN research in business, using 168 documents from the Scopus database covering 2007 to 2025. It uses several methods that include descriptive bibliometrics, Bradford's Law, Lotka's Law, performance analysis, keyword co-occurrence analysis, thematic mapping using Callon centrality and density measures, Multiple Correspondence Analysis, co-citation network analysis, and logistic growth life cycle modeling - all done with the bibliometrix R package v4.0 (Aria and Cuccurullo, 2017) and VOSviewer (Van Eck and Waltman, 2010). The study offers both a summary and a detailed map of the field's intellectual structure. To the best of the authors' knowledge, this is the first study to apply this combination of methods to ANN research across all major business subfields over 19 years.

The study is guided by five research questions

RQ1: What are the overall characteristics and growth dynamics of ANN research in business sciences over the period 2007-2025?

RQ2: Which authors, institutions, and countries have made the most important contributions, and what collaborative patterns characterize their interactions?

RQ3: Which documents have most shaped the intellectual foundations of ANN research in business sciences?

RQ4: What thematic clusters and conceptual structures define the field's current intellectual landscape, and how have they evolved?

RQ5: What emerging research frontiers and future directions can be identified from the field's developmental trajectory?

The remainder of this article is structured as follows. Section 2 reviews the related literature. Section 3 describes the data collection procedure, search strategy, and analytical methods. Section 4 presents the results across descriptive, performance, and science mapping dimensions. Section 5 discusses the findings. Section 6 draws conclusions, acknowledges limitations, and proposes future research directions.

LITERATURE REVIEW

The use of Artificial Neural Networks (ANNs) in business has attracted increasing scholarly attention, resulting in a range of studies encompassing systematic reviews, topic modelling studies, and bibliometric mappings. Together, these studies offer a helpful background for this research while showing ongoing issues with methods and topics. Wong *et al.* (2000) provided an early comprehensive bibliography of 302 ANN research articles published between 1994 and 1998, identifying production, finance, marketing, and information systems as the dominant application areas and establishing one of the first systematic evidence of ANN's growing footprint in business research. Building on this foundation, Tkáč and Verner (2016) examined 412 articles from 1994 to 2015, sorting them by area of use, network design, and learning method, and found that ANN research in business has mainly focused on predicting financial problems, bankruptcy, and stock prices. Building on this finance focus, Singh *et al.* (2021) combined data from many studies to show that ANNs predict better than traditional statistical methods like Linear Discriminant Analysis in bankruptcy and stock market forecasts, while pointing out that areas like foreign exchange and commodity trading are less studied. Bahrammirzaee (2010) provides a comparative review of artificial intelligence techniques in financial markets, highlighting the effectiveness of neural networks, expert systems, and hybrid models in addressing nonlinear and time-varying financial problems Yang *et al.* (2024) provide a detailed review of AI in business and economics research, tracking its growth from 1966 to 2020 and noting a sharp increase after 2017, with topics moving from decision support systems to machine learning and big data.

Beyond finance, another group of studies examines the use of ANNs in specific management areas Saheb *et al.* (2023) compared neural network models for credit risk assessment in commercial banking, arguing that traditional methods no longer meet the requirements of modern financial risk management Praveen and Suguna (2020) argued that dynamic ANN methods outperform traditional static methods for sentiment analysis and customer behavior prediction Khtou *et al.* (2024) conducted a systematic literature review of ML and ANN applications in sustainable supply chain management, demonstrating their utility in optimizing the triple-bottom-line dimensions of sustainability and offering implementation guidelines for practitioners Soori *et al.* (2023) provided a broader review demonstrating ANN

utility across demand forecasting, inventory optimization, and supplier evaluation in supply chain management. Most recently, Sakib *et al*. (2025) conducted a bibliometric analysis of 86 Scopus articles on neural networks and HRM. Their findings show rapid growth in the field, with Chinese and Indian researchers leading recent developments. The study also notes a thematic shift from convolutional neural networks to broader machine learning and AI applications in HRM. Although these studies show the flexibility of ANNs across business areas, each focuses on a single field and does not try to combine insights across disciplines.

Another group of studies has used more exploratory or data-driven methods to broadly map the ANN field Elmsili and Outtaj (2018). Used Latent Dirichlet allocation on 1,106 papers, finding seven main topic groups including customer relationship management, banking risk, and macroeconomic forecasting, though their exploratory approach did not allow detailed analysis of citation impact or changes over time Baysal *et al*. (2023). Performed a VOSviewer-based bibliometric analysis of 545 Web of Science articles, identifying machine learning and the Internet of Things, big data, and natural language processing as the most prominent keywords and finding that publications in this area have continued to increase since 2018. The study most similar to our present study is (Perannagari and Gupta, 2022), who used science mapping to follow the development of ANN research in business and suggested more focus on deep learning, while noting that the fast changes in the field require ongoing updates.

Overall, the existing research indicates a major limitation: most previous studies focus on one area or use only one method like narrative review, topic modeling, or bibliometrics, and no earlier study has offered a multi-method bibliometric analysis covering a major range of business areas such as accounting, marketing, finance, human resource management, corporate social responsibility, and entrepreneurship within a single framework. This study addresses these gaps by using co-authorship, keyword co-occurrence, thematic mapping, factorial, co-citation, and life cycle analyses to provide a complete map of the field's intellectual structure.

METHODOLOGY

Research Design

This study uses bibliometric analysis to systematically map the research on ANN in business sciences. Bibliometric analysis is a quantitative method that looks at publications, citations, author patterns, and intellectual networks (Donthu *et al*. 2021). Unlike traditional literature reviews, bibliometric analysis uses reproducible quantitative procedures (Donthu *et al*. 2021). The method has three steps: (1) collecting data and corpus construction; (2) descriptive bibliometric analysis; and (3) science mapping and network analysis.

Data Collection and Search Strategy

The data for this study were retrieved from the Scopus database, one of the two most extensive scientific databases available for bibliometric research (Chadegani *et al*., 2013; Harzing and Alakangas, 2016). A detailed list of keywords was constructed by combining two groups of search terms: (1) business science areas, and (2) ANN-related words. The same ANN terms were applied to all business areas. The six business areas studied are: Accounting, Marketing, Finance, Entrepreneurship, Corporate Social Responsibility (CSR), and Human Resource Management (HRM). ANN-related words include: "Artificial Neural Network," "ANN," "neural network modeling." All these terms were searched for in titles, abstracts, and author keywords. You can see Appendix Table A1.

The database search was conducted in February 2026. The first search found 255 documents. Three filters were applied: (1) a language filter retaining only English-language documents; (2) limiting the types to articles, conference papers, and book chapters; and (3) requiring full bibliographic records. After these filters, the final set included 168 documents published between 2007 and 2025. As shown in Appendix Figure 1A. Of the 255 initially retrieved documents, 30 were excluded due to time span, 5 were excluded due to language (non-English), 9 due to document type (editorials, letters, etc.), and 43 were excluded after title and abstract screening, yielding the final corpus of 168 documents. You can see Appendix Figure 1A for the PRISMA flowchart.

Bibliometric Tools

All bibliometric analyses were conducted using R version 4.4.1 and the bibliometrix package version 4.0, especially its visual interface Biblioshiny (Aria and Cuccurullo, 2017). For network visualization tasks like co-authorship networks, keyword co-occurrence maps, and co-citation networks, VOSviewer (Van Eck *et al*., Waltman, 2010), was used as an additional tool.

Analytical Framework

The analytical framework has three parts. The first part, descriptive analysis, gives a quantitative overview of the corpus's structure, including yearly publication growth, citation patterns, and authorship trends. The second part, performance analysis, evaluates the contributions of individual authors, institutions, and countries. Lotka's Law is used to study the frequency distribution of scientific productivity, and Bradford's Law identifies the main journals sharing research in this area. The third part, science mapping, includes keyword co-occurrence analysis, thematic mapping using Callon centrality and density measures (Callon *et al*. 1991; Cobo *et al*. 2011), Multiple Correspondence Analysis (MCA) to find latent conceptual themes, co-citation network analysis to show the field's intellectual base, and logistic growth

life cycle modeling to project how the field will develop. Table 1 indicates the full analytical framework.

RESULTS

Descriptive Overview of the Dataset

Table 2 shows the main features of the 168 documents found in Scopus. The collection covers 18 years from 2007 to 2025, showing the fairly recent use of ANN in business studies and the growing interest in this area. The dataset includes 145 different sources, showing a highly dispersed publication landscape. The average age of the documents is 5.80 years, showing that the collection is recent and matches the fast growth of ANN use in business fields.

A total of 479 authors contributed to the corpus, with the vast majority (95.2%) participating in multi-authored documents, underscoring the collaborative nature of ANN research in business contexts. Also, articles constitute the dominant document type (108 out of 168, or 64.3%), followed by conference papers (41; 24.4%), book chapters (16; 9.5%), and review articles (3; 1.8%).

Table 1: Summary of Analytical Framework.

Analysis Type	Method	Tool	Output
Descriptive Overview	Publication trends, citation analysis, Bradford's Law, Lotka's Law	Biblioshiny	Annual production, citation rates, source distribution, productivity distribution
Performance Analysis	Author/country/institution productivity, collaboration rates	Biblioshiny	Rankings, h-index, MCP ratios
Science Mapping	Co-word analysis, thematic mapping, MCA, co-citation networks, life cycle modelling	Biblioshiny + VOSviewer	Thematic clusters, conceptual structure, intellectual foundations, maturity projection

Source(s): Authors' own creation.

Table 1A: Keyword Matrix.

Business Science subfields	Alternative terms used for Business subfields	Alternative terms for ANN
Accounting	"Accounting" or "Financial accounting" or "Managerial accounting" or "Cost accounting" or "Auditing" or "audit" or "Accounting standards" or "fiscal" or "IFRS" or" financial statement " or"Financial Information" or"accounting information" or"financial reporting"	"Artificial neural network" or " Neural Network Modelling Approach" Or " ANN" or "Neural Network Modelling Approach" OR "neural network modelling"
Marketing	"Marketing" or "Market research" or "Consumer behavior" or "Marketing strategy" or "Digital marketing" or "Advertising" or "Brand management" or "Social media marketing" or "Pricing Strategy" or "Distribution and Retail Marketing"	
Finance	"finance" or "green finance" or "Corporate finance" or "Financial analysis" or "Investment decisions" or "Funding decisions" or "Financial risk management" or "Management control" or "Capital budgeting" or " financial reporting" or"budgeting "	
Entrepreneurship	"Entrepreneurship " or " Business creation" or "Startup development" or "Business model" or "Business plan" or "Venture capital" or "Entrepreneurial finance"	
Corporate Social Responsibility	"Corporate Social Responsibility" or "CSR" or "Corporate Environment Sustainability" or "Business ethics" or "Environmental management" or "Social entrepreneurship" or "Sustainable business practices"	
Human Resource	"Human Resource" OR "Human Resource Management" OR "HRM" OR "Recruitment " OR " Employee Training " OR "Career Management" OR "Employee Motivation"	

Table 2: Main Bibliometric Information of the Corpus (2007-2025).

Description	Results
Main Information	
Timespan	2007-2025
Sources (Journals, Books, etc.)	145
Documents	168
Annual Growth Rate (%)	16.45
Document Average Age (years)	5.80
Average Citations per Document	17.46
References	8,152
Document Contents	
Keywords Plus (ID)	879
Author's Keywords (DE)	585
Authors	
Total Authors	479
Authors of Single-Authored Documents	24
Authors Collaboration	
Single-Authored Documents	25
Co-Authors per Document	3.04
International Co-Authorship (%)	23.21
Document types	
Articles	108
Conference Papers	41
Book Chapters	16
Reviews	3

Source(s): Biblioshiny output.

Annual Scientific Production and Citation Trends

Figure 1 illustrates the annual scientific production of ANN research in business sciences over the study period. Output remained modest during the early phase (2007-2017), fluctuating between one and six documents per year. A notable inflection point occurs around 2018, after which production increases more steadily, reaching 11 documents in 2018, 13 in 2021, 20 in 2022, 21 in 2023, 19 in 2024, and 31 in 2025. The overall Annual Growth Rate of 16.45% confirms that the field is in a phase of active and sustained expansion.

Figure 2 shows the average number of citations each article gets per year. There are three clear peaks: 2010 (average 237.50 citations per article), 2016 (89.80), and 2020 (30.00). These peaks are attributable to the disproportionate citation accumulation of a small number of highly influential publications. The overall average of 17.46 citations per article shows this group of papers is cited moderately. As expected, the most recent years (2023-2025) have lower average citation numbers because new articles have not had much time to be cited.

Life Cycle Analysis of the Field

The logistic growth model applied to the total production data estimates the field's saturation point (K) at 1,680 documents, with the inflection point (tm) the year of highest yearly output expected around 2036 (tm=30.32 years from the start, corresponding to 2036-2037). The growth period (delta_t) is 21.44 years, showing how long the field's main growth phase lasts.

These estimates show that ANN research in business sciences is now in the early to middle part of its growth, far from its expected peak. The 10th percentile of total production (about 168

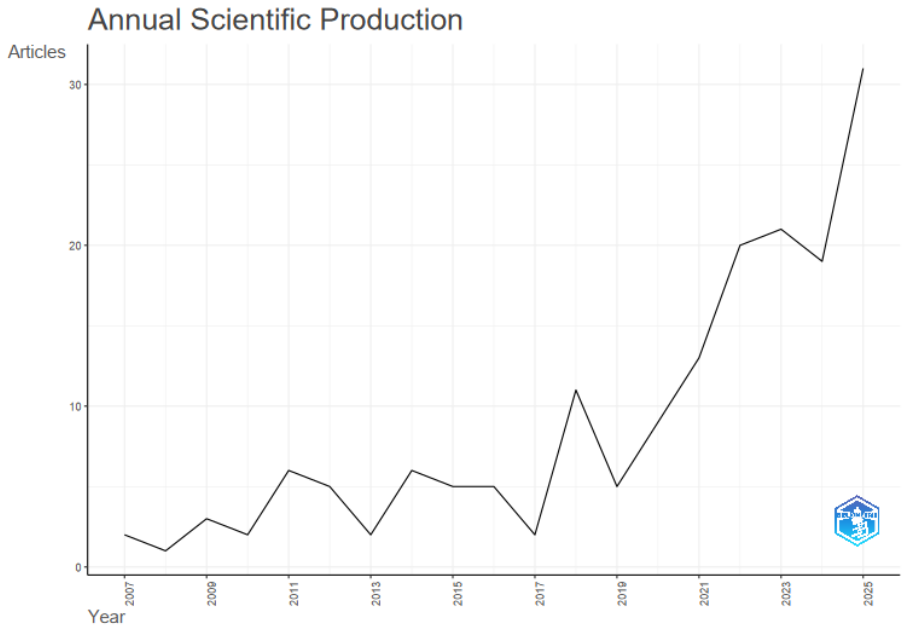


Figure 1: The annual scientific production of ANN research in business sciences. Source(s): Biblioshiny output.

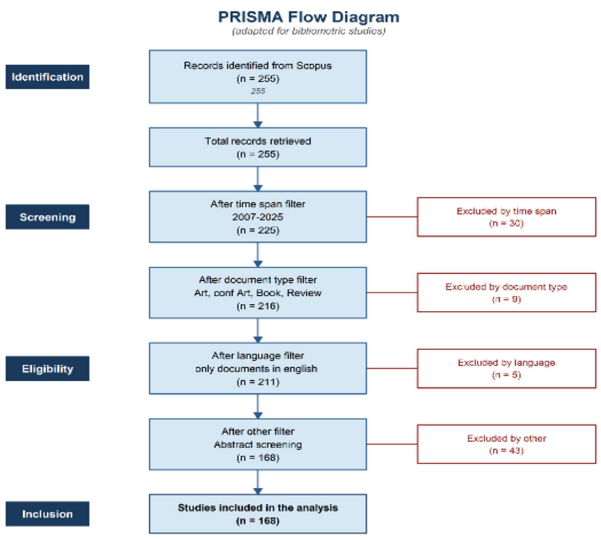


Figure 1A: The PRISMA flowchart. Source(s): Authors' own creation using Biblioshiny.

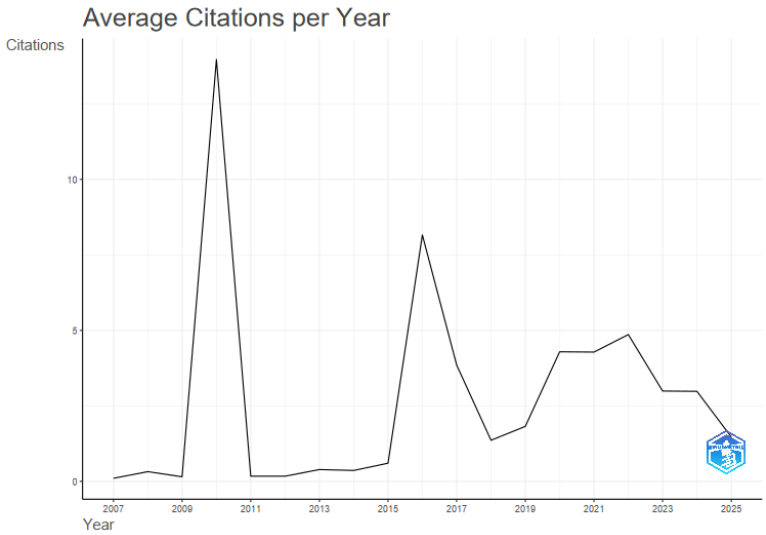


Figure 2: The average citations per year in the field ANN-based research. Source(s): Biblioshiny output.

documents) matches the current number of papers, meaning the field has just passed its early stage as of February 2026. The 90th percentile is expected around 2047. This growth pattern suggests the field is still in an early developmental phase, offering considerable scope. As with all logistic growth projections derived from bibliometric data, these estimates are sensitive to corpus size and search parameters and should be interpreted as indicative trends rather than precise forecasts.

Most Relevant Sources and Bradford's Law

The 168 documents were published across 145 distinct sources, reflecting a highly fragmented publication landscape. Table 3 presents the eleven most productive sources. Four sources jointly lead with three publications each: Advances in Environmental Biology, Advances in Intelligent Systems and Computing, Studies in Computational Intelligence, and Sustainability (Switzerland). No single journal dominates the output, which is characteristic of an interdisciplinary field drawing simultaneously from computer science, management, finance, and sustainability literatures.

Looking at citation impact, Technological Forecasting and Social Change (TC=195) and Systems (TC=135) emerge as the most influential sources, even though they each contributed only two documents. This suggests these journals are especially important for high-quality ANN research. Journal of Cleaner Production (TC=140) also has a strong influence across the field. Using Bradford's Law on the collection indicates three clear concentration zones, which are summarized in Table 4.

As shown in Figure 3, Zone 1 includes 34 sources producing 57 documents (about 33.9% of the total). Zone 2 has 56 sources producing 56 documents (33.3%), and Zone 3 has 55 sources producing 55 documents (32.7%). The relatively large number of sources in Zone 1, indicates that there is no leading speciality journal in this research area.

Most Relevant Authors and Affiliations

Table 5 and Figure 4 show the ten authors with the most publications in the corpus. Dwivedi YK and Singh S each have three publications, with Singh S having a higher fractionalized score (0.87), showing more independent work. Eight authors have two publications each.

In terms of institutional affiliations, CETYS Universidad (Mexico) leads with five documents, followed by Fuzhou University (China), Islamic Azad University (Iran), and The University of Jordan (four documents each). This institutional distribution reflects a notable decentralisation of ANN research in business. As shown in Figure 5.

Lotka's Law: Scientific Productivity Distribution

Table 6 indicates the frequency distribution of scientific productivity according to Lotka's Law (Lotka, 1926). The results show that 449 authors (93.7%) wrote exactly one document, 28 authors (5.8%) wrote two documents, and only two authors (0.4%) wrote three documents. Figure 6 indicates that the number of publications and how often authors appear closely follow Lotka's Law in this field.

Countries' Scientific Production and International Collaboration

Table 7 indicates the corresponding author country distribution. China leads with 33 articles (19.6% of the total), followed by India (20 articles, 11.9%) and Turkey (9 articles, 5.4%). The USA has 6 articles (3.6%). Although China and India have the most articles, there are notable differences in how often they are cited.

As shown in Figure 7, France, though contributing only by one document, leads in total citations (TC=463), attributable to the highly influential comparative survey by Bahrammirzaee (2010), whose Scopus-recorded corresponding affiliation is French. Similarly, the United Kingdom achieves the second-highest total citations (TC=454, average 151.3 per article across three documents), and Malaysia, with five articles, records a remarkable average of 51.4 citations per document.

Regarding international collaboration, and as shown in Figures 8 and 9, China's MCP ratio of 21.2% indicates active international collaboration, while India's MCP ratio of 10.0% indicates that most

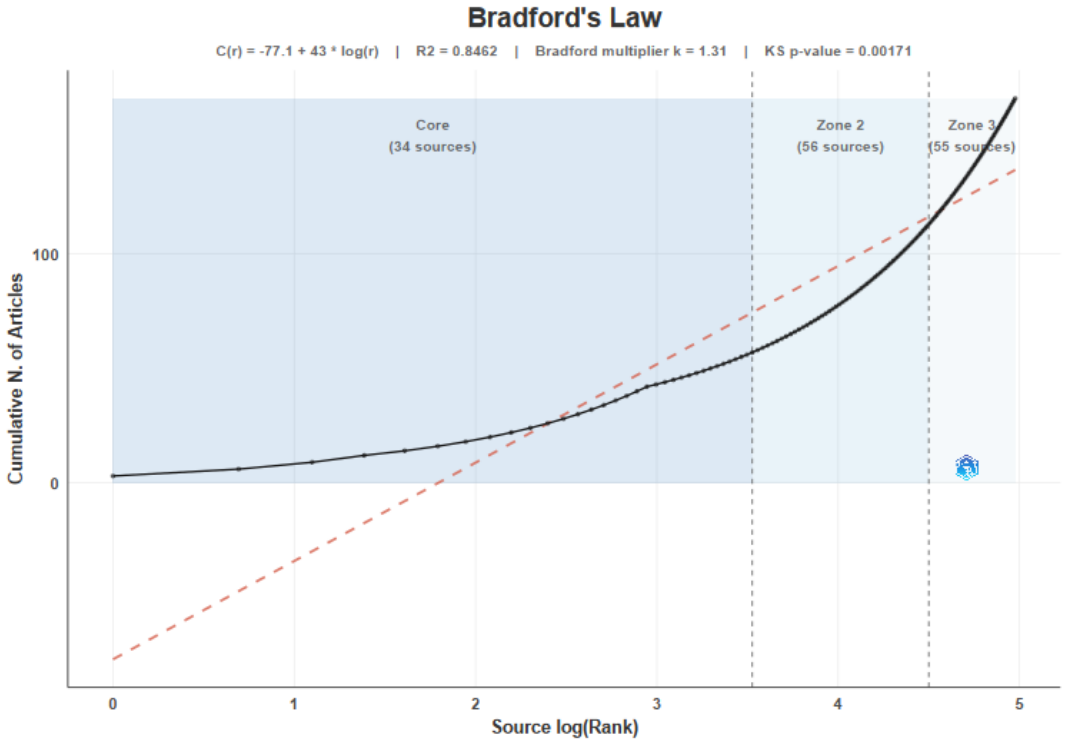


Figure 3: The application of Bradford's Law. Source(s): Biblioshiny output.

Table 3: Eleven Most Relevant Sources by Number of Publications.

Source	Articles	h-index	TC
Advances in Environmental Biology	3	-	-
Advances in Intelligent Systems and Computing	3	-	-
Studies in Computational Intelligence	3	2	11
Sustainability (Switzerland)	3	3	37
Advances in Decision Sciences	2	2	31
IEEE Access	2	2	64
Journal of Cleaner Production	2	2	140
Neural Computing and Applications	2	-	-
Scientific Reports	2	2	24
Systems	2	2	135
Technological Forecasting and Social Change	2	2	195

Source(s): Biblioshiny output.

Table 4: Bradford's Law - Source Distribution across Three Zones.

Zone	Sources	Articles	Cumulative Articles
Zone 1 (Core)	34	57	57
Zone 2 (Intermediate)	56	56	113
Zone 3 (Periphery)	55	55	168
Total	145	168	168

Source(s): Biblioshiny output.

Indian work stays within the country. Malaysia's MCP ratio of 100%, meaning all five of its articles had international co-authors, makes it a very connected partner, even though it publishes fewer articles. Jordan (MCP=40%) and Iran (MCP=25%) also show more international cooperation than average, compared to their number of publications.

Most Globally and Locally Cited Documents and References

Table 8 and Figure 10 indicate the 10 most-cited documents in the corpus. The most cited work is Bahrammirzaee (2010), published in Neural Computing and Applications. It has 463 total citations and averages 27.2 per year. The second most cited work is (Tkáč and Verner 2016) it has 292 total citations and an average of 26.5 per year Sharma *et al.* (2021) have 262 total citations. It has the highest adjusted citation count (10.20) and yearly citation rate (43.7) in the group. It is the most influential recent study. This study uses SEM-ANN to examine SMS advertising and consumer buying intention. Its fast citation growth indicates that combining SEM with ANN methods is a key area of growth. Wang *et al.* (2022), Yan *et al.* (2022) also support this trend of combining SEM and ANN methods. The tenth-most-cited document is (Wu *et al.*, 2023), which has 64 citations. It is much newer than the others, showing a quick rise and early impact in sustainability research.

As shown in Figure 11, the most locally cited documents, those getting the most citations from within the corpus itself, are Sharma *et al.* (2021, 4 local citations), Tkáč and Verner (2016, 4 local citations), Zakaryazad and Duman (2016, 3 local citations), Bahrammirzaee (2010, 3 local citations), and Omar *et al.* (2017, 3 local citations).

As shown in Figure 12, the locally most cited reference overall is Hair *et al.* (2019) on PLS-SEM reporting (5 local citations), reflecting the prevalence of structural equation modelling as a companion methodology to ANN in the corpus.

Most Frequent Keywords and Temporal Evolution

The keyword analysis, using the Keywords Plus (ID) field from Scopus, finds 879 unique terms across 168 documents. As shown in Figure 13, the 20 most common keywords are clearly related to ANN: 'neural networks' appears 61 times, followed by 'artificial neural network' (52) and 'artificial neural networks' (28), totaling 141 mentions. Besides these ANN-related terms, the analysis highlights important business areas like 'commerce' and 'marketing' (17 mentions each), 'forecasting' (12), 'decision making' (11), 'sales' (10), and 'finance' (9). The mention of 'structural equation modeling' (8 times) reflects the growing integration of ANN with complementary quantitative methods.

Figure 14 presents the most frequent keywords across the corpus offering a clearer visualization of the dominant ANN-related vocabulary relative to core business domain keywords.

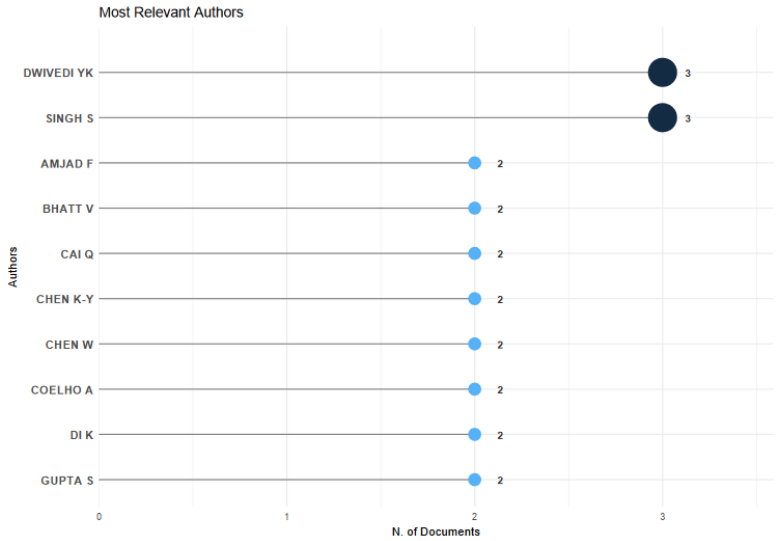


Figure 4: Top ten most relevant authors. Source(s): Biblioshiny output.

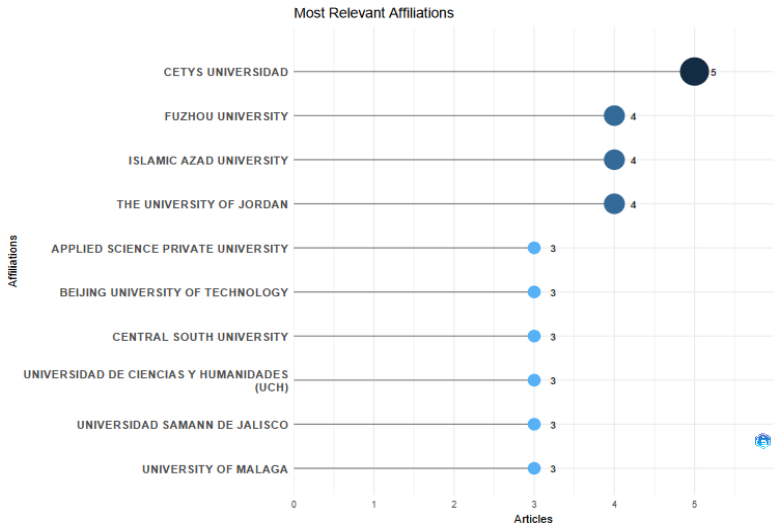


Figure 5: Top ten most relevant affiliations. Source(s): Biblioshiny output.

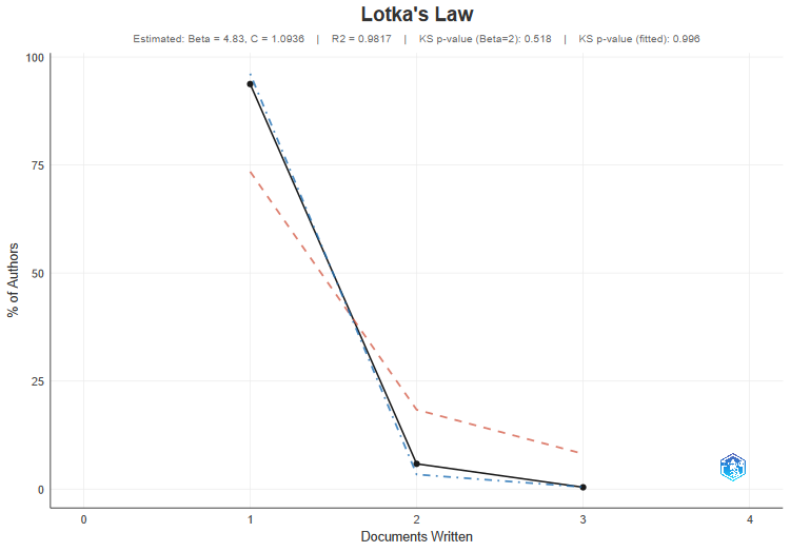


Figure 6: Frequency Distribution of Scientific Productivity (Lotka's Law). Source(s): Biblioshiny output.

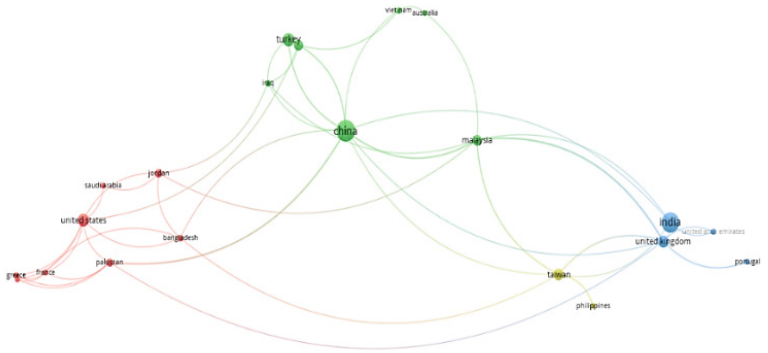


Figure 7: Ten most cited countries. Source(s): Biblioshiny output.

Table 5: Ten Most Productive Authors by Number of Publications.

Author	Articles	Articles (Fractionalized)
Dwivedi YK	3	0.70
Singh S	3	0.87
Amjad F	2	0.53
Bhatt V	2	0.37
Cai Q	2	0.50
Chen K-Y	2	0.83
Coelho A	2	0.50
Gupta S	2	1.00
Levine DS	2	0.83
López-Leyva JA	2	0.53

Source(s): Biblioshiny output.

The changes in keyword frequencies over time (Figure 15) show important long-term patterns. 'Commerce' and 'marketing' have been rising strongly since 2020, showing how ANN is used in online business and consumer behavior studies. The topic trend analysis indicates that 'green finance' and 'pls-sem' are truly new research areas, both with median years of 2025, the latest in the dataset, indicating these terms have become important only in the most recent part of the research.

Thematic Map and Intellectual Structure

The thematic map, created by analyzing how keywords appear together using the Louvain clustering method (n=250, minimum frequency=2), indicates eight theme groups, as shown in Figure 16.

Table 9 lists each group with its Callon centrality and density scores. The groups are divided based on median values: the median Callon centrality is 8.05, and the median density is 109.63.

Table 6: Frequency Distribution of Scientific Productivity According to Lotka's Law.

Documents Written	Number of Authors	Proportion of Authors
1	449	0.937
2	28	0.058
3	2	0.004

Source(s): Biblioshiny output.

Groups scoring above both medians are called Motor Themes (important and well-developed); above median density but below median centrality are Niche Themes; above median centrality but below median density are Basic Themes; and below both medians are Emerging or Declining Themes.

Motor Themes

Two clusters are identified as motor themes, representing the well-established and strategically central core of Artificial Neural Network (ANN) research within the business sciences. Cluster 3 ('commerce and finance', centrality=9.65, density=173.57) is the most internally cohesive cluster, emphasizing the application of artificial neural networks in financial markets, risk assessment, and commercial decision-making. Cluster 5 ('decision making', centrality=10.57, density=132.22) links ANN-based decision support, which utilizes artificial neural networks to guide business decisions, with sales analytics and cost modeling. The high centrality and density of both clusters confirm that financial and commercial applications of artificial neural networks form the mature, dominant core of the field.

Niche Themes

Two clusters are positioned within the niche theme quadrant, characterized by high internal cohesion but limited integration

Table 7: Top Countries by Corresponding Author Affiliation - Publication and Citation Profile.

Country	Articles	Freq. (%)	SCP	MCP	TC (Avg/doc)
China	33	19.6	26	7	339 (10.3)
India	20	11.9	18	2	206 (10.3)
Turkey	9	5.4	7	2	158 (17.6)
USA	6	3.6	4	2	114 (19.0)
Jordan	5	3.0	3	2	79 (15.8)
Malaysia	5	3.0	0	5	257 (51.4)
Iran	4	2.4	3	1	-
United Kingdom	3	1.8	1	2	454 (151.3)
Mexico	3	1.8	3	0	-
France (1 doc)	-	-	-	-	463 (463.0)

Source(s): Biblioshiny output.

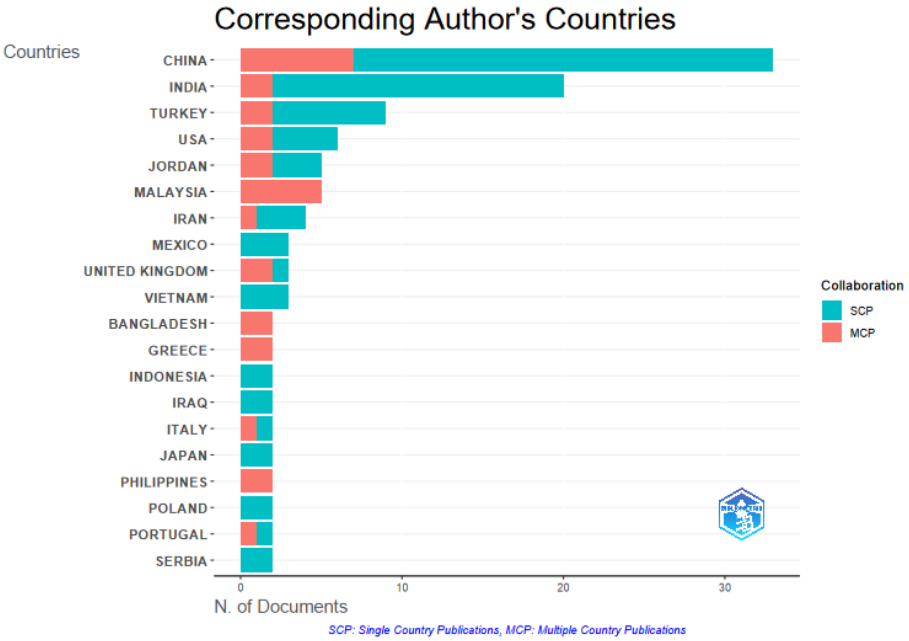


Figure 8: The most relevant countries by corresponding authors. Source(s): Biblioshiny output.

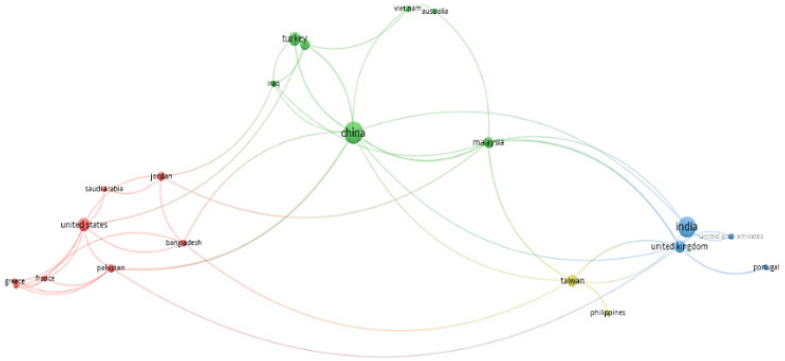


Figure 9: Country scientific production map. Source(s): VosViewer output.

Table 8: Ten Most Globally Cited Documents in the Corpus.

Paper	TC	TC/Year	Norm. TC	Source
Bahrammirzaee, 2010	463	27.2	1.95	Neural Comput Appl
Tkáč and Verner, 2016	292	26.5	3.25	Appl Soft Comput J
Sharma *et al.*, 2021	262	43.7	10.20	Comput Hum Behav
Wang *et al.*, 2022	150	30.0	6.17	Technol Forecast Soc Change
Yan *et al.*, 2022	125	25.0	5.14	Systems
Zakaryazad *et al.*, Duman, 2016	116	10.5	1.29	Neurocomputing
Leong *et al.*, 2020	103	14.7	3.43	Expert Syst Appl
Dadhich *et al.*, Hiran, 2022	76	15.2	3.13	J Clean Prod
Omar *et al.*, 2017	71	7.1	1.84	J Financ Crime
Wu *et al.*, 2023	64	16.0	5.35	J Clean Prod

Source(s): Biblioshiny output.

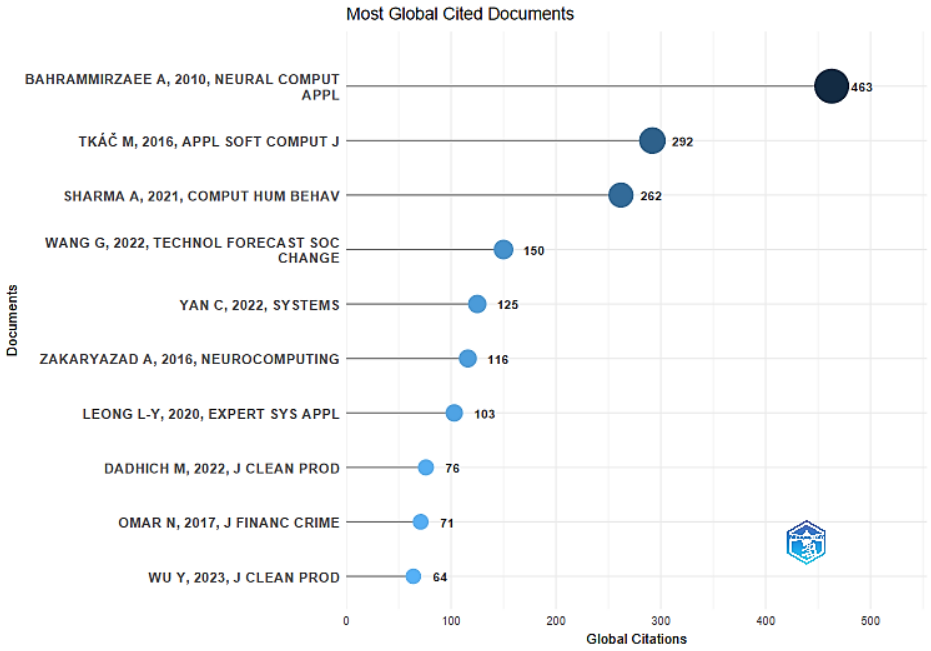


Figure 10: Most globally cited documents. Source(s): Biblioshiny output.

with the broader field. Cluster 2 ('artificial neural network', centrality=7.61, density=110.74) is internally well-developed. Artificial Neural Networks (ANNs) are computational models inspired by biological neural networks. This cluster groups ANN as a predictive and classification tool, although its methods have not been widely adopted in business research. Cluster 8 ('sustainable development', centrality=2.20, density=143.89) exhibits the lowest centrality but a high-density score, indicating a self-contained and expanding community focused on ANN applications in Corporate Social Responsibility (CSR), green finance, and entrepreneurship. The emergence of this niche theme, along with the trend toward 'green finance' toward 2025, suggests it is nascent rather than in decline.

Basic Themes

Two clusters are located in this quadrant, reflecting high connectivity across the field but limited internal specialization. Cluster 1 ('neural networks', centrality = 15.40, density = 85.51) possesses the highest centrality score, serving as the primary connective hub for the field. Its below-median density results from its large size, as the largest cluster by a significant margin (255 co-occurrences), with keyword pairs distributed across a broad topic space that includes foundational Artificial Neural Network (ANN) concepts, marketing, forecasting, investments, and machine learning. This distribution structurally reduces density. Cluster 4 ('neural-networks and innovation', centrality=8.48, density=108.51) also spans a wide range of topics, connecting artificial neural networks to competition, innovation, and data mining, and maintains high cross-field relevance without deep internal specialization.

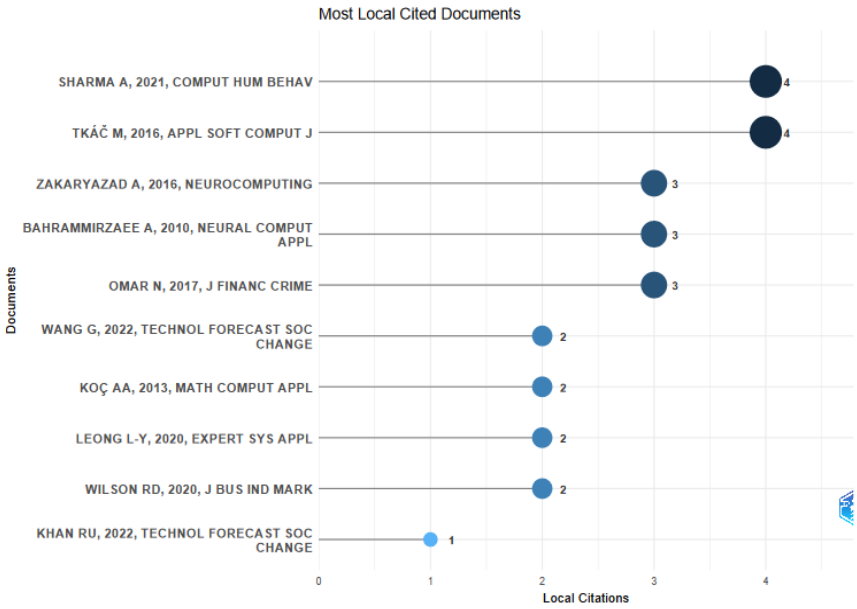


Figure 11: Most Locally Cited Documents. Source(s): Biblioshiny output.

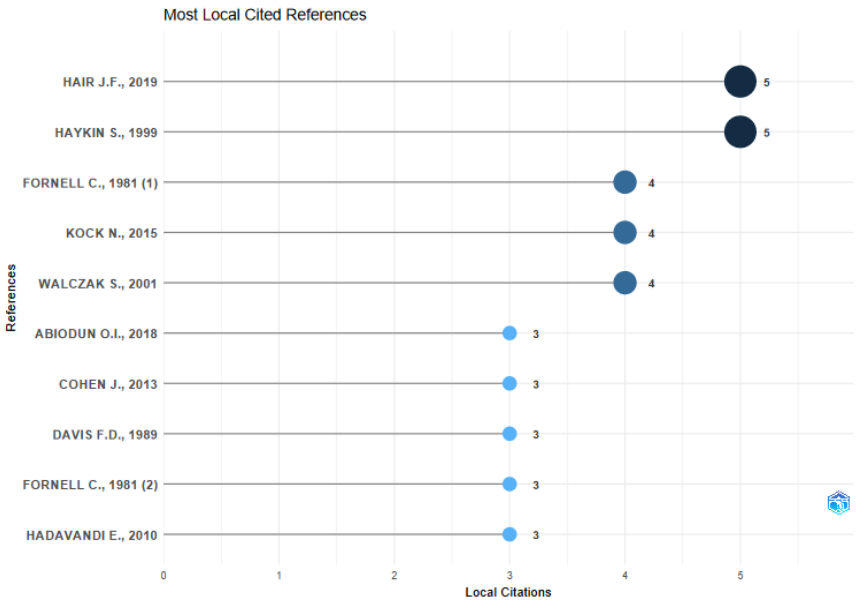


Figure 12: Most Locally Cited references. Source(s): Biblioshiny output.

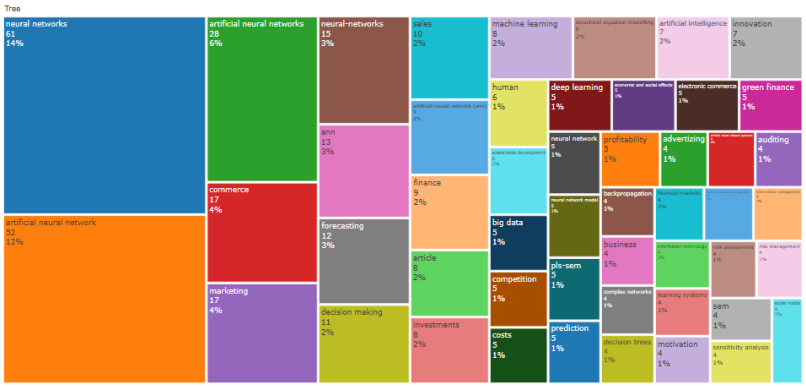


Figure 13: The most relevant words used in ANN research in business sciences. Source(s): Biblioshiny output.

Table 9: Thematic Clusters: Labels, Key Terms, Callon Centrality, and Density Scores.

Sl. No.	Cluster Label	Key Terms	Centrality	Density
1.	Neural Networks	neural networks, marketing, forecasting, investments, machine learning	15.40 (Rank 8)	85.51 (Rank 2)
2.	Artificial Neural Network	artificial neural network, prediction, classification, PCA	7.61 (Rank 4)	110.74 (Rank 5)
3.	Commerce and Finance	commerce, finance, financial markets, risk assessment	9.65 (Rank 6)	173.57 (Rank 8)
4.	Neural-Networks and Innovation	neural-networks, competition, innovation, data mining	8.48 (Rank 5)	108.51 (Rank 4)
5.	Decision Making	decision making, sales, costs, neural network model	10.57 (Rank 7)	132.22 (Rank 6)
6.	ANN Abbreviation	ann, abbreviation usage	7.53 (Rank 3)	93.85 (Rank 3)
7.	SEM-ANN Methods	structural equation modelling, PLS-SEM, hybrid methods	3.75 (Rank 2)	75.48 (Rank 1)
8.	Sustainable Development	sustainable development, CSR, green finance, entrepreneurship	2.20 (Rank 1)	143.89 (Rank 7)

Source(s): Biblioshiny output.

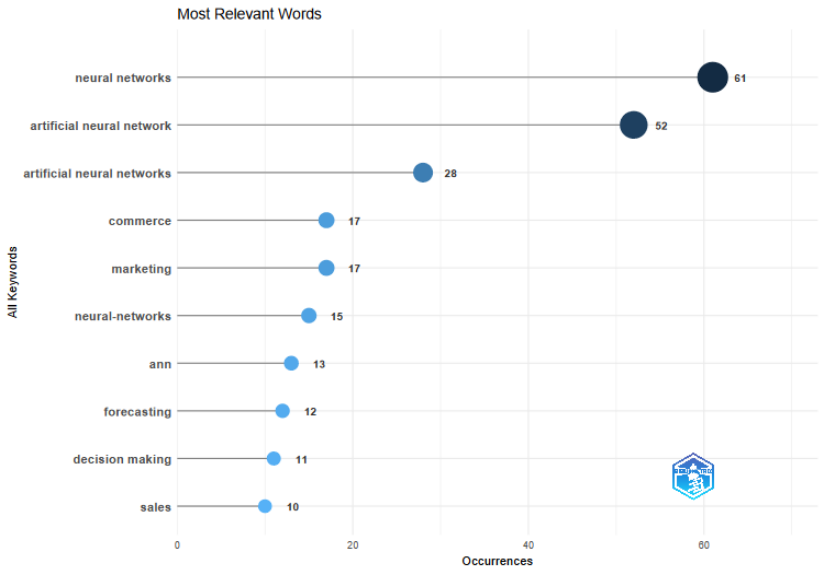


Figure 14: Ten most relevant words used in ANN-based research. Source(s): Biblioshiny output.

Emerging Themes

Two clusters are situated in this quadrant. Cluster 6 ('ANN' abbreviation, centrality=7.53, density=93.85) comprises papers that use 'ANN' (artificial neural network) as a shorthand across various application areas; this cluster reflects a preprocessing artifact stemming from unsystematic abbreviation usage across the corpus rather than a coherent research subfield, and should be interpreted accordingly. Cluster 7 ('structural equation modeling', centrality=3.75, density=75.48) encompasses SEM-ANN hybrid methods, which combine structural equation modeling with artificial neural networks, as well as information quality research. Its placement in the emerging or declining quadrant suggests that, despite increasing citation impact for individual SEM-ANN studies, this methodological cluster has not yet attained sufficient centrality or internal density to be classified as a niche or motor theme at the field level. Determining whether this cluster is emerging or declining requires longitudinal analysis beyond a single cross-sectional study.

Factorial Analysis (Multiple Correspondence Analysis)

Figure 17 shows the Multiple Correspondence Analysis (MCA), conducted on merged keywords with a minimum degree

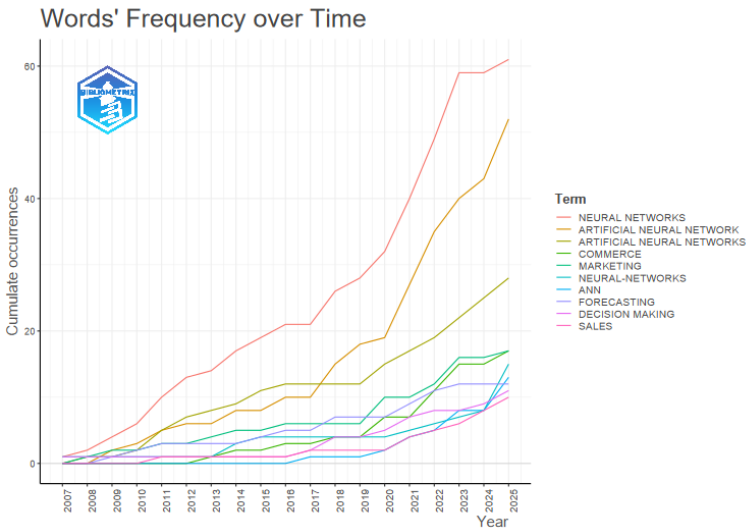


Figure 15: Word frequency over time. Source(s): Biblioshiny output.

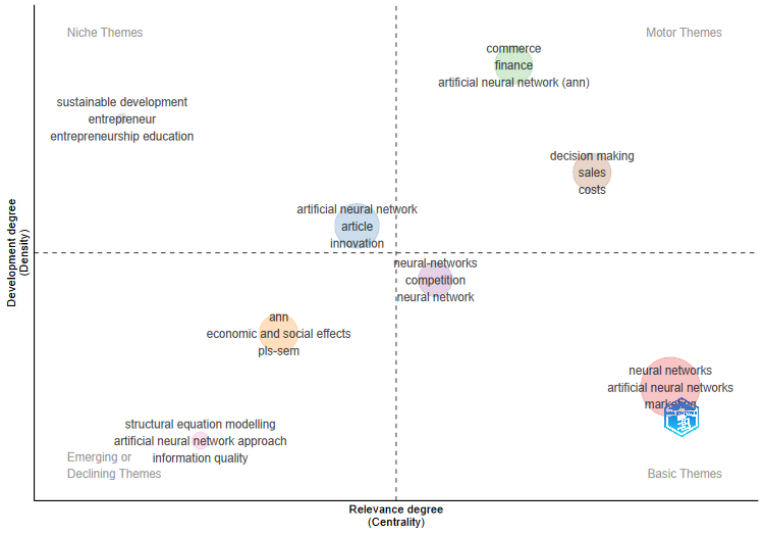


Figure 16: Thematic map. Source(s): Biblioshiny output.

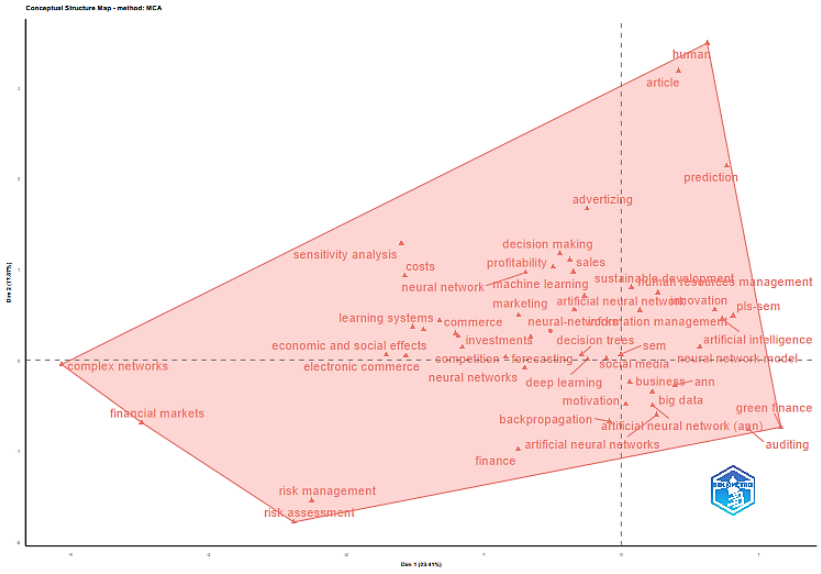


Figure 17: Conceptual structure map using multiple correspondence analysis. Source(s): Biblioshiny output.



Figure 18: Authors Co-Citation Network. Source(s): Biblioshiny output.

threshold of 4 and a maximum of 8 clusters, resulting in a two-dimensional conceptual structure map. Dimension 1 (Dim1) represents the primary axis of conceptual variation, contrasting application-domain terms such as 'commerce' (Dim1= -1.20), 'investments' (Dim1=-1.19), 'costs' (Dim1= -1.57), 'marketing' (Dim1= -0.75), and 'forecasting' (Dim1 = -0.84) with AI-oriented terms including 'artificial intelligence' (Dim1=0.73), 'innovation' (Dim1= 0.68), and 'ann' (Dim1=0.39). Dimension 2 (Dim2) delineates a secondary axis that contrasts behavioral and decision-oriented terms, such as 'decision making' (Dim2 = 1.17), 'sales' (Dim2=1.10), and 'machine learning' (Dim2 = 0.97), from financial and investment-oriented terms, including 'finance' (Dim2 = -0.98) and methodological AI- related concepts such as 'artificial neural networks' (Dim2 = -0.60). The term 'sustainable development' (Dim1=0.07, Dim2=0.80) is located near the origin of Dim1 and toward the upper end of Dim2, suggesting limited integration with the field's established conceptual core. This observation aligns with its identification as a niche thematic area.

Co-Citation Network Analysis

Figure 18 shows the co-citation network analysis; three main research clusters can be discussed. Cluster 1 focuses on the methods behind hybrid SEM-ANN research, based on Hair *et al.* (2019) about PLS-SEM reporting and Henseler *et al.* (2015) about discriminant validity. This indicates the methods that support the fast-growing SEM-ANN hybrid studies. Cluster 2 includes (Cohen, 2013) about statistical power analysis and (Liebana-Cabanillas *et al.*, 2017) about adoption of m-commerce. This reflects the behavioral management research in which many SEM-ANN studies are conducted. Cluster 3 covers the technical- quantitative foundations, based on (Walczak, 2001) on ANN for financial forecasting, (Hadavandi *et al.*, 2010) on stock price forecasting with ANNs, and (Tkáč and Verner, 2016). This three-group setup indicates that the main foundations of ANN research in business are threefold: technical ANN basics, behavioral-management theory, and SEM-ANN hybrid methods.

DISCUSSION

Growth Trajectory and Field Maturity

Annual scientific output remained low and variable during the field's first decade but increased steadily from 2018 onward, reaching a peak of 31 publications in 2025 with annual growth rate of 16.45%. The life cycle analysis supports this: with the maximum expected number of documents at 1,680 and the turning point around 2036, the field is now in its early growth phase.

This suggests the field is still expanding in terms of output volume, though the thematic and co-citation analyses indicate that certain application domains such as Marketing and Commerce and methodological foundations such as the hybrid PLS-ANN approach are already well-consolidated.

Collaborative Patterns and Geographic Distribution

The authorship analysis indicates a field with a pronounced collaborative orientation, averaging 3.04 co-authors per paper. The international co-authorship rate of 23.21% is significant but indicates most collaboration activity remains intra-national. China and India lead in the number of publications (19.6% and 11.9%, respectively), but their average citations per paper are about 10.3, which is relatively low. In contrast, France's single paper has 463 citations, the United Kingdom averages 151.3 citations across three papers, and Malaysia's five internationally co-authored papers average 51.4 citations each. France's average

of 463 citations per document results from a single landmark review paper (Bahrammirzaee, 2010), while the UK's average of 151.3 citations is based on only three documents.

Citation Impact and the Canonical Literature

The lasting influence of (Bahrammirzaee, 2010), with 463 total citations more than 15 years after publication, indicates that comparative, cross-method reviews of ANN use in finance keep a strong long-term impact, serving as starting points for new researchers entering the field. The ongoing citation popularity of Tkáč and Verner (2016) also indicates the steady need for organized, cross-field reviews of ANN use in business. More interesting is the citation pattern of recent papers: Sharma *et al*. (2021)' study applied a hybrid PLS-SEM-ANN approach to investigate consumer purchase intention in SMS advertising, recorded the highest normalized total citations (10.20) and yearly citation rate (43.7) among studies analyzed. Similarly, the citation trajectories of SEM-ANN studies by Wang *et al*. (2022); Yan *et al*. (2022) suggest growing scholarly recognition of this methodological approach across business research contexts. This aligns with the thematic map's identification of SEM-ANN as an emerging theme.

Thematic Structure and Research Priorities

The thematic map identifies two motor themes: commerce and finance (centrality=9.65, density=173.57) and decision-making support (centrality=10.57, density=132.22), confirming their role as the structural and intellectual core of ANN research in business sciences.

The SEM-ANN methods cluster occupies an emerging position (centrality=3.75, density=75.48), reflecting a nascent stream yet to achieve internal consolidation or broader disciplinary integration. Linking SEM-ANN methods to the field's motor themes would enrich analytical depth and facilitate the diffusion of specialized methodological knowledge.

The sustainable development cluster is a nascent niche. Despite its niche positioning (centrality= 2.20, density=143.89), the median publication year of 2025 for "green finance" and "PLS-SEM" suggests an emerging growth frontier rather than a stagnating niche. ANN applications in corporate sustainability, green finance, and CSR thus represent the field's most active developmental trajectory, driven by growing institutional pressure toward sustainability imperatives.

Conceptual Structure and the SEM-ANN Convergence

The MCA shows that the primary axis of conceptual variation opposes application-domain papers from technical methodology papers, while a secondary axis distinguishes behavioral-decision studies from financial ones. This two-part structure shows that ANN research in business operates in at least two main areas that have remained mostly separate rather than combined. The co-citation network analysis indicates that these areas have different key influences: technical ANN research relies on (Tkáč and Verner, 2016; Walczak, 2001; Wong *et al*., 2000) behavioral management research relies on (Cohen, 2013; Liebana-Cabanillas *et al*., 2017) and SEM-ANN hybrid research relies on (Hair *et al*., 2019; Henseler *et al*., 2015).

Limitations

There are some limitations to note. First, using only Scopus means that papers published only in Web of Science, Google Scholar, or specific subject databases might be missing, which could cause a coverage bias. Second, focusing only on English-language documents might leave out important ANN-in-business research in Arabic, Chinese, Portuguese, or other languages, especially since Chinese and Middle Eastern contributors are important according to the country-level analysis. Third, the keyword search method involves decisions about what to include that might leave out studies on the edges of the covered sub-disciplines.

CONCLUSION

This study offered a detailed bibliometric analysis of Artificial Neural Network (ANN) research in business, based on 168 documents from Scopus covering 2007 to 2025. Using several methods, including descriptive bibliometrics, performance analysis, Bradford's Law, Lotka's Law, life cycle modelling, keyword co-occurrence analysis, thematic mapping, Multiple Correspondence Analysis, and co-citation network analysis. This study provided both a quantitative portrait and a structured science mapping of a rapidly evolving interdisciplinary field.

The analysis showed that ANN research in business is steadily growing, with an annual growth rate of 16.45% and a record 31 papers published in 2025. The life cycle model predicts the field will reach its highest productivity around 2036, indicating that the field is currently in a pivotal early growth phase. Lotka's Law analysis indicates that most authors (93.7%) are single-publication authors, a pattern consistent with fields in early developmental stages. China and India publish the most papers, but France and the UK get more citations per paper, suggesting that more papers do not always mean more impact.

The thematic analysis reveals two motor themes: commerce and finance, and decision-making support as the field's established pillars, alongside two niche themes (ANN prediction/classification and sustainable development) and SEM-ANN as an emerging theme warranting further consolidation.

This study extends and complements the work of (Tkáč and Verner, 2016; Perannagari and Gupta, 2022) by broadening the disciplinary scope, lengthening the temporal horizon, and employing a more comprehensive suite of science-mapping and network-analysis techniques. The findings provide a structured,

evidence-based framework for researchers to navigate the field, highlighting established pillars, underexplored areas, and emerging frontiers. Several avenues for future research are evident: the integration of Artificial Neural Networks (ANN) with sustainability, green finance, and Corporate Social Responsibility (CSR) frameworks requires further theoretical exploration; the SEM-ANN emerging cluster should be linked to the motor themes through cross-disciplinary empirical studies; and replicating this analysis using databases such as Web of Science or EBSCO, as well as incorporating non-English literature, would produce a more complete and internationally representative understanding.

ABBREVIATIONS

ANN/ANNs: Artificial Neural Network(s); **CSR:** Corporate Social Responsibility; **HRM:** Human Resource Management; **SEM:** Structural Equation Modeling; **PLS:** Partial Least Squares; **MCA:** Multiple Correspondence Analysis; **TC:** Total Citations; **SCP:** Single Country Publication; **MCP:** Multiple Country Publication; **IoT:** Internet of Things; **PRISMA:** Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Dr. Meryem Ayad holds a PhD in Management Science from Hassan First University. Her research focuses on the application of artificial intelligence and machine learning in accounting and management sciences. She has published in peer-reviewed international journals and conference proceedings on topics such as AI implications in accounting subfields, accounting information quality, and systematic literature reviews of AI in accounting. She has also contributed to comparative studies on financial reporting frameworks. She currently serves as a Research Program Officer at the National Center for Scientific and Technical Research in Rabat, supporting national research coordination and scientific development.

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AUTHORS CONTRIBUTION

Conceptualization: Dr. Meryem Ayad; **Methodology:** Dr. Meryem Ayad, Pr. Said EL Mezouari; **Formal Analysis:** Dr. Meryem Ayad; **Writing - Original Draft:** Dr. Meryem Ayad; **Writing - Review:** Dr. Meryem Ayad, Pr. Said EL Mezouari.

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