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## Article

# Artificial intelligence research in organizations: a bibliometric approach

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# Artificial intelligence research in organizations: a bibliometric approach

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# Artificial intelligence research in organizations: a bibliometric approach

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## ABSTRACT

Although more and more researchers have paid attention to artificial intelligence research in organizations across different subdivided fields in recent years, there is still a lack of integrative and comprehensive research on AI in organizations. Building upon previous quantitative and qualitative studies in the artificial intelligence literature, this study presents a bibliometric analysis of articles on artificial intelligence in the fields of management, business, and applied psychology up to June 2nd, 2023. The research explores the landscape of artificial intelligence articles, highlighting key intellectual contributions and research constituents such as journals, authors, countries, institutions, and topics. Additionally, the study investigates the intellectual structure and overlay visualization of keywords to identify popular topics and trends in recent artificial intelligence research. The findings offer readers a systematic understanding of artificial intelligence development and provide new insights that expand upon existing knowledge in artificial intelligence within management, business, and applied psychology.

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## SUBJECTS


Work & Organizational  
Psychology; Artificial  
Intelligence; Information  
Technology

## 1. Introduction

Since the formal introduction of Artificial Intelligence (AI) in 1956, there have been significant technological advancements in this field. Milestones such as IBM's Deep Blue defeating the chess champion in 1997, Google's AlphaGo defeating the Go master in 2016, and the launch of OpenAI's ChatGPT in 2020 all exemplify the remarkable progress in AI technology. Over the past decade, due to the vast potential of AI technology, AI has become integral to organizational operations (Alnamrouti et al., 2022). Enterprises leverage AI to conduct precise customer portrait analysis, identify consumer behavior patterns, and discern customer needs through technologies like social public opinion analysis and natural language processing (Davenport et al., 2020; Davidsson et al., 2020; Fan et al., 2020; Gaspar et al., 2016). AI also aids in candidate screening and evaluation for businesses (Black & van Esch, 2020; Hamilton & Davison, 2018), and provides credit assessment and risk strategies for enterprises (Sood, 2020). More specifically, Netflix's recommendation systems, Google's search engines, IBM's Watson, and Microsoft's Azure are all typical examples of how AI can be used in the enterprise.

While more and more enterprises are using AI in their daily operations, there has been significant growth in AI research within the realms of management, business, and applied psychology (Dwivedi et al., 2021; Martínez-López & Casillas, 2013; Mikalef & Gupta, 2021). Several notable reviews have examined the current landscape and advancements in AI research within specific domains. For instance, Loureiro et al. (2021) scrutinized 404 articles in business-related fields spanning from 1970 to 2019, revealing that AI research in business can be categorized into four primary areas and 18 topics. Arsenyan and Piepenbrink (2024) conducted a review of 6,324 articles in management-related fields from 1990 to

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2020, highlighting that prior AI research predominantly focused on 41 distinct topics. Lee et al. (2023) undertook a systematic review and analysis of articles on AI published in 31 journals covering information systems, business, management, and operations management, pinpointing 70 research topics. Dhamija and Bag (2020) analyzed 1,854 articles between 2018 and 2019 to uncover six emerging clusters of AI in operations management. Mariani et al. (2023) carried out a comprehensive analysis of 1,448 published AI research articles across marketing, consumer research, and psychology, identifying four thematic clusters of AI across these fields. Plathottam et al. (2023) delved into the research literature on AI and machine learning in manufacturing, outlining the potential benefits and challenges of their application in the manufacturing sector.

Although this body of literature significantly enriches our understanding of AI research in management, business, and applied psychology, there are several limitations to consider. Firstly, the majority of review articles employ qualitative methods to analyze research across various time periods (e.g. Jan et al., 2023). The analysis of research topics and content is often influenced by the authors' subjective perspectives and understanding of the field. Secondly, current research tends to focus more on specific areas such as manufacturing (Li et al., 2017), human resource management (Li et al., 2023), marketing (Donthu, Kumar, Pattnaik, et al., 2021), and healthcare (Ali et al., 2023), instead of providing a comprehensive overview of organizational issues related to AI. Thirdly, these studies often overlook the changing popularity of different topics over time, key contributors (such as authors, countries, and institutions), and the intellectual structure of AI research. Lastly, there is a lack of in-depth exploration of author cooperation networks and keyword co-occurrence networks in these articles. Therefore, significant questions highlighting the need for integrative and comprehensive research on AI in organizations remain unanswered. This is surprising, given the growing use of AI-based technologies in organizations and the long-standing calls from researchers for such integrative and comprehensive studies (Von Krogh, 2018).

In recent years, bibliometrics has gained popularity among researchers in the management and business fields due to its distinct advantages (Donthu, Kumar, Pandey, et al., 2021; Donthu et al., 2020; Khan et al., 2021; Merigó & Yang, 2017). Through bibliometric analysis, scholars can visually represent the current research status, knowledge structure, and development context of one or more topics. This method also helps in identifying the most influential articles and journals in the research field, author collaborations, and emerging trends and evolution of research topics (Donthu, Kumar, Pandey, et al., 2021; Verma & Gustafsson, 2020). To address the limitations of previous studies and fill the research gap in the AI literature, this study aims to utilize bibliometric quantitative research methods to analyze the comprehensive landscape of AI research in the fields of management, business, and applied psychology, and address specific research questions.

1. What are the publishing and citation trends in AI research?
2. What is the knowledge structure of the fields of management, business, and applied psychology related to AI?
3. In what direction should future research advance the development of AI?

This study contributes by presenting the latest trends in publication and citation in AI research, aiding both new and experienced researchers in evaluating productivity and impact. Additionally, the analysis of co-citation and keyword co-occurrence networks sheds light on the knowledge structure of the field, facilitating a deeper understanding of its development. Lastly, through scientific mapping of keywords, the study outlines the evolution and trends of AI research, offering valuable insights for future research directions.

This study continues with the following structure. [Section 2](#) will outline the methodology employed. [Section 3](#) will then present the key results, such as trends in publications/citations over time, insights into influential authors/institutions/countries, a co-authorship network analysis, co-citation mappings, co-occurrence networks, and overlay visualization of keywords. [Section 4](#) will discuss the contributions of the current work and potential limitations. Avenues for future research in this domain will also be outlined. [Section 5](#) will conclude the study by summarizing the main findings and takeaways.

## 2. Method

The Web of Science Core Collection database was searched for peer-reviewed articles on AI topics in the fields of management, business, and applied psychology as of June 2nd, 2023. We selected this database as it contains more than 250 subject categories across the sciences, social sciences, arts, and humanities spanning back to 1990 (and even earlier) and is an influential database accepted over the world.<sup>1</sup> Initially, a total of 5,864 articles were identified. After an initial screening process, 5,561 articles containing 'artificial intelligence' in their titles, abstracts, or keywords were retained for further analysis. These articles were then used for bibliometric analysis. The search strategy employed for this analysis is depicted in Figure 1.

In order to enhance the effectiveness of VOSviewer's (version 1.6.19) bibliometric analysis, keywords were recoded to account for synonyms, singular and plural forms, spelling variations, and symbol discrepancies. Initially, 119 words were extracted from a pool of 5,561 articles. Subsequently, synonyms for identical topic words were consolidated. For instance, terms like 'AI', 'artificial intelligence', 'artificial intelligence (AI)', 'artificial-intelligence', 'distributed artificial intelligence', and 'explainable artificial intelligence' were all uniformly recoded as 'AI'. Similarly, 'decision-making' was standardized as 'decision making', while variations like 'neural network', 'neural networks', 'neural-network', and 'neural-networks' were all coded as 'NN'. Additionally, overly broad terms such as 'model', 'system', 'information', and 'networks' were excluded from the recoding process. To enhance the visual presentation of our results in co-authorship network analysis, co-citation analysis, keyword co-occurrence analysis, and overlay visualization of keyword analysis, we adjusted certain parameters in the 'analysis tab' of the 'action panel'. For instance, when performing co-authorship network analysis, we set the 'Attraction' and 'Repulsion' parameters to 2 and -1, respectively (see [supplemental material](#) for specific settings).

## 3. Results

### 3.1. Descriptive results

The analysis presented in Figure 2 demonstrates a general upward trend in annual publications and citations within the field. While other areas of AI research experienced more progress in the 1990s, AI research in management, business, and applied psychology did not see significant development until that time. The evolution of AI research in these fields can be segmented into distinct stages: slow growth

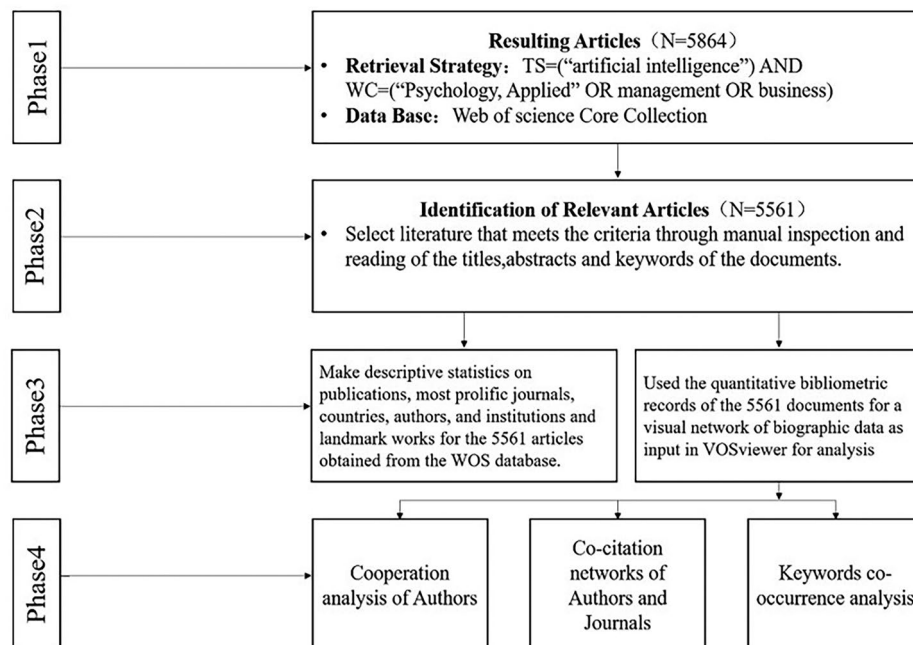
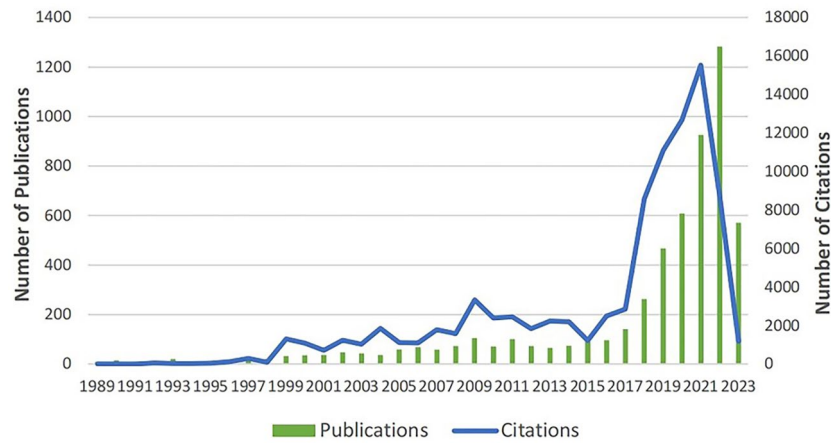


Figure 1. Methodology of research.



**Figure 2.** Annual trends in publications and citations for AI research from 1989 to 2023 ( $n=5561$ ).

**Table 1.** The top 10 journals by number of articles published in this field.

Rank	Journal	TP	TC	JCR	IF(five year)
1	Expert Systems with Applications	591	20025	Q1	8.3
2	Technological Forecasting and Social Change	134	2935	Q1	12
3	International Journal of Production Research	104	3453	Q1	8.8
4	Journal of Business Research	101	2412	Q1	11.5
5	European Journal of Operational Research	93	3725	Q1	6.4
6	Annals of Operations Research	74	1273	Q1	4.6
7	IEEE Transactions on Engineering Management	58	433	Q2	5.8
8	Electronic Markets	43	988	Q1	7.9
9	Psychology & Marketing	39	872	Q1	6.3
10	Journal of Manufacturing Systems	37	1892	Q1	11.1

Note: TP=Total Publications; TC=Total Citations; JCR=Journal Citation Report; IF=Impact Factor.

in papers and citations from 1989 to 1998, a gradual increase from 1999 to 2009, a slight decline between 2010 and 2014, and a rapid rise in both published papers and citations since 2015. By 2022, there were 1,283 annual publications and 8,662 citations. This trajectory aligns with Haenlein and Kaplan's (2019) characterization of the development of AI research across different time periods, indicating a period of increased productivity in AI research within the realms of management science, business studies, and applied psychology since 2015.

The significant increase in publications since 2015 can be attributed to various factors. Firstly, advancements in computing power and algorithms have greatly accelerated progress in AI research and its practical applications. For example, in 2015, Google's AlphaGo, utilizing artificial neural networks and deep learning, defeated a human professional chess player, marking a significant milestone in AI research. Secondly, the widespread adoption of AI technology by organizations across different domains has created new challenges for managers, prompting researchers to offer solutions (Bamberger, 2018; Von Krogh, 2018).

### 3.2. Contributions of research constituents

#### 3.2.1. Most prolific journals, countries, authors, and institutions

Table 1 displays the top 10 journals based on the number of published articles. Expert Systems with Applications stands out with the highest paper count (TP = 591) and over 20,000 total citations. As of June 2nd, 2023, the journal had already published 57 articles in 2023, further solidifying its strong academic standing in the AI field. Following closely are Technological Forecasting and Social Change (TP = 134), the International Journal of Production Research (TP = 104), and the Journal of Business Research

(TP = 101). These leading journals in management, business, applied psychology, and operations research and management science reflect the increasing influence of AI research in these fields.

Table 2 presents data on the top 10 authors with the highest number of published articles. Dwivedi, affiliated with Swansea University, holds the highest number of publications (TP = 22) in the past four years. Following closely are Kietzmann from Victoria University (TP = 16) and Chatterjee from the Indian Institute of Management (TP = 14). The leading authors in this area show a predominant interest in operations research and management science, business and economics, psychology, and computer science.

Table 3 displays the top 10 countries in terms of article production in the field of AI. Leading the list is the United States with 1,128 articles, followed closely by China (TP = 1,006) and the United Kingdom (TP = 534). Notably, the United States also boasts the highest total number of citations (TC = 30,629), indicating its significant research output and influence in the AI domain. Furthermore, it is noteworthy that a total of 19 countries have published over 100 articles, underscoring the increasing global importance and interest in AI research.

Table 4 displays the top 10 units based on the number of published articles in the field. Leading the list is the Hong Kong Polytechnic University from China with 62 publications, followed by the University of Economic Studies Bucharest from Romania with 55, and Swansea University from the UK with 32. Notably, despite the National University of Singapore having only 29 articles, it garnered a total of 1,740 citations, resulting in an average of 60 citations per article. This high average citation count among the top 10 units indicates the significant impact of the National University of Singapore in the field of AI research.

### 3.2.2. Landmark works

Table 5 presents the top 15 most-cited articles in the fields of management, business, and applied psychology, which account for 0.26% of the total 5,561 papers. Huang and Rust's (2018) article stand out as the most cited, with a total citation count of 777. This article delves into the potential for AI to replace humans in service jobs, proposing an AI job substitution theory that outlines the evolution of AI intelligence levels from mechanical to empathic tasks. The implications of this shift on human employment have sparked significant scholarly interest. Following closely is Wirtz et al.'s (2018) paper

**Table 2.** Top 10 authors by number of published articles in this field.

Rank	Author	TP	TC	H-index	Institution
1	Dwivedi, Yogesh K.	22	879	22	Swansea University
2	Kietzmann, Jan	16	584	24	University of Victoria
3	Chatterjee, Sheshadri	14	410	35	Indian Institute of Management Ranchi
4	Van Esch, Patrick	13	304	19	Kennesaw State University
5	Gupta, Shivam	12	464	42	NEOMA Business Sch
6	Vrontis, Demetris	12	356	19	University of Nicosia
7	Malik, Ashish	11	159	24	University of Newcastle
8	Parida, Vinit	11	690	47	Lulea University of Technology
9	Chaudhuri, Ranjan	10	213	20	Leonard de Vinci Pole Univ
10	Haenlein, Michael	10	1261	26	ESCP Business School

Note: TP=Total Publication; TC=Total Citation.

**Table 3.** Top 10 countries by number of articles published in this field.

Rank	Country	TP	Percentage (n/5561)	TC	CCP	TLS
1	USA	1128	20.28%	30629	27.15	7442
2	CHINA	1006	18.09%	18285	18.18	4531
3	ENGLAND	534	9.60%	14157	26.51	4931
4	INDIA	360	6.47%	5257	14.60	2713
5	GERMANY	359	6.46%	7942	22.12	2690
6	FRANCE	336	6.04%	7405	22.04	3533
7	AUSTRALIA	284	5.11%	7369	25.95	2722
8	ITALY	251	4.51%	3618	14.41	1871
9	SPAIN	244	4.39%	4398	18.02	982
10	CANADA	223	4.01%	3442	15.43	1444

Note: TP=Total Publications; TC=Total Citations; CPP=Citations per Publication; CCP=Total Citations / Total Publications.

**Table 4.** Top 10 institutions by number of published articles in this field.

Rank	Institution	Country	TP	TC	CCP	TLS
1	Hong Kong Polytech Univ	China	62	2232	36.00	46
2	Bucharest Univ Econ Studies	Romania	55	59	1.07	8
3	Swansea Univ	Britain.	32	1111	34.72	92
4	Nanyang Technol Univ	Singapore	31	719	23.19	19
5	Neoma Business Sch	France	31	812	26.19	71
6	Natl Univ Singapore	Singapore	29	1740	60.00	58
7	Univ Johannesburg	South Africa	29	822	28.34	52
8	MIT	America	26	829	31.88	10
9	Swinburne Univ Technol	Australia	26	638	24.54	30
10	Tsinghua Univ	China	25	357	14.28	13

Note: TP=Total Publications; TC=Total Citations; CPP=Citations per Publication; CPP=Total Citations / Total Publications; TLS=Total Link Strength.

with 655 citations, which explores the opportunities and challenges of service robots compared to frontline service employees, highlighting the ethical and social considerations at various levels. Ranked third in annual citations with 646 mentions, Tao et al. (2018) discusses the transition to intelligent manufacturing driven by Internet of Things (IoT), cloud computing, big data, and AI technologies. Notably, Yang et al.'s (2021) article, ranked thirteenth, introduces a DBN-based state classification multi-sensor health diagnosis method leveraging deep machine learning for structural health applications, boasting a high citation rate per year of 231. Remarkably, each of the top 15 articles has gained over 400 citations.

### 3.3. Co-authorship network analysis

To gain insights into current collaborations and key researchers in the fields of management, business, and applied psychology, we utilized VOSviewer's 'Co-authorship' feature to visualize the collaborative network of researchers. We established a threshold of 5 for articles related to AI research, resulting in a network of 99 researchers (Figure 3). Node size in the visualization corresponds to the number of published articles, with larger nodes indicating more co-publications. The connections between nodes signify collaborative ties between authors. Notably, out of the 47 clusters identified, 29 consisted of only one author, prompting us to focus on clusters with 5 or more authors for further analysis. Table 6 provides details on the clustering relationships among authors, number of publications, average publication year, and research topics covered.

Cluster 1 (red), led by Dwivedi, comprises 11 authors. The average publication year of articles in this cluster is 2021.64, with an average publication volume of 8.37, indicating high productivity. Research by these authors focus on the implementation of emerging technologies like AI and blockchain in business settings, alongside a focus on consumer behavior and market trends.

Cluster 2 (green), led by Gunasekaran, comprises 7 authors. The average publication year of articles by authors in this cluster is 2020.95, making it the cluster with the older average publication year. In terms of productivity, authors in this cluster publish an average of 6.43 papers, which is lower than other clusters. Their research focuses on advocating for an economic growth model of the circular economy, with a particular interest in exploring how AI, big data analytics, and supply chain management technologies can facilitate sustainable business development.

Cluster 3 (steel blue), led by Haenlein, is composed of 6 authors. The average publication year of articles published by authors in this cluster is 2020.74, making it the oldest cluster in terms of average publication year. With an average of 8 papers issued, this cluster demonstrates high productivity. Authors in this cluster exhibit a particular focus on privacy concerns and moral and ethical implications related to the application of AI, robotics, and other technologies, distinguishing them from other clusters.

Cluster 4 (yellow), led by Malik, comprises 5 authors. The average publication year of articles by authors in this cluster is 2022.12, making it the youngest cluster. These authors have been notably active in recent years, with an average publication year of 2022. The average number of articles published by authors in this cluster is 7.2. They excel in bibliometric analysis, addressing not only human resource management and employee experience enhancement within enterprises but also sustainable finance in society.

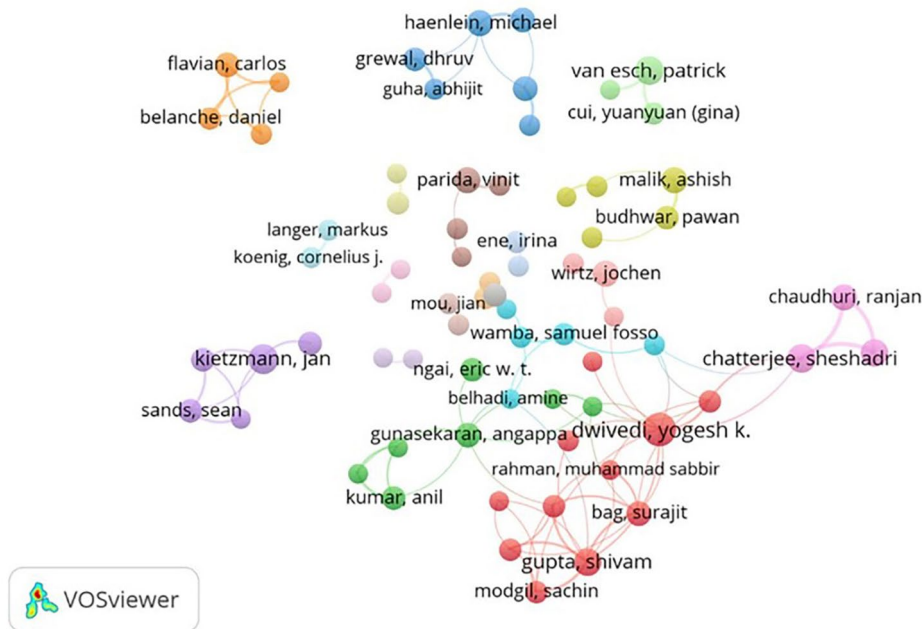
**Table 5.** Landmark AI research in management, business, and applied psychology.

Rank	Year	Title	Author	Journal	TC	C/Y
1	2018	Artificial Intelligence in Service	Huang, Ming-Hui; Rust, Roland T.	Journal of Service Research	777	155.40
2	2018	Brave new world: service robots in the frontline	Wirtz, Jochen; Patterson, Paul G; Kunz, Werner H.; et al.	Journal of Service Management	655	131.00
3	2018	Data-driven smart manufacturing	Tao, Fei; Qi, Qinglin; Liu, Ang; et al.	Journal of Manufacturing Systems	646	129.20
4	2013	Application of decision-making techniques in supplier selection: A systematic review of literature	Chai, Junyi; Liu, James N. K; Ngai, Eric W. T.	Expert Systems with Applications	604	60.40
5	2004	Credit rating analysis with support vector machines and neural networks: a market comparative study	Huang, Z; Chen, Hc; Hsu, Cj; et al.	Decision Support Systems	595	31.32
6	2007	Yahoo! for Amazon: Sentiment Extraction from Small Talk on the Web	Das, Sanjiv R; Chen, Mike Y.	Management Science	593	37.06
7	2018	Smart manufacturing	Kusiak, Andrew	International journal Of Production Research	587	117.40
8	2019	Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence	Kaplan, Andreas; Haenlein, Michael	Business Horizons	574	143.50
9	2019	Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal	Warner, Kar S.R; Waeger, Maximilian	Long Range Planning	552	138.00
10	2009	A survey of dynamic scheduling in manufacturing systems	Ouelhadj, Djamila; Petrovic, Sanja	Journal of Scheduling	547	39.07
11	2004a	The State of the Art of Nurse Rostering	Burke, Ek; De Causmaecker, P; Vanden Berghe, G; et al.	Journal of Scheduling	539	28.37
12	2017	The Future of Retailing	Grewal, Dhruv; Roggeveen, Anne L; Nordfalt, Jens	Journal of Retailing	478	79.67
13	2021	Hunger games search: Visions, conception, implementation, deep analysis, perspectives, and towards performance shifts	Yang, Yutao; Chen, Huiling; Heidari, Ali Asghar; et al.	Expert Systems with Applications	462	231.00
14	2013	Failure diagnosis using deep belief learning based health state classification	Tamilselvan, Prasanna; Wang, Pingfeng	Reliability Engineering & System Safety	434	43.40
15	2020	How artificial intelligence will change the future of marketing	Davenport, Thomas; Guha, Abhijit; Grewal, Dhruv; et al.	Journal of The Academy of Marketing Science	420	140.00

TC: Total Citation; C/Y: Citation per year.

Cluster 5 (purple), led by Kietzmann, comprises 5 authors with an average publication year of 2021.15, indicating a relatively mature body of work. This cluster stands out for its high productivity, with an average of 9 papers per author. Their research has significantly contributed to the advancement of AI in management, business, and applied psychology. These authors specialize in machine learning, particularly in the realms of AI-driven B2B marketing, the dissemination of true and false information on social media, and delving into the customer experience within marketing.

Cluster 6 (aqua), represented by Wamba, comprises 5 authors. The average publication year of articles by these authors is 2021.65. With an average of 5.8 papers published per author, this cluster has the



**Figure 3.** Author collaboration network.

lowest productivity. Specializing in literature reviews, the authors focus on supply chain elasticity and show a keen interest in social innovation.

Within the six author clusters identified, there is a noticeable trend of stronger cooperative relationships among authors within the same cluster, suggesting a stable collaboration dynamic. Conversely, there is a lack of cooperation between authors from different clusters, highlighting the potential benefits of fostering collaboration across diverse clusters to advance the field.

### 3.4. Co-citation analyses

#### 3.4.1. Journal co-citation analysis

Journal co-citation occurs when two journals are cited by the same literature, demonstrating the correlation between different journals and disciplines. In Figure 4, a co-citation network is displayed for 71 journals with a minimum threshold of 450 citations. The size of the nodes represents the total number of co-citations for each journal, while the lines between nodes indicate the co-citation relationship and similarities in publication topics. The figure highlights four clusters, each identified by a different color and unique characteristics.

Topic cluster 1 (red) is named 'Computer Science and Operations Research', comprising 27 journals. Representative journals include *Expert Systems with Applications*, *Artificial Intelligence*, *Decision Support Systems*, and *Lecture Notes in Computer Science*. These journals primarily explore computer system structures, program systems, AI technology, and related subjects. *Expert Systems with Applications* garnered the most citations (TC = 3,768), followed by the *International Journal of Production Research* (TC = 2,313). The cluster delves into operational research and management science, featuring journals like the *European Journal of Operational Research* and *Computers & Operations Research*. Additionally, sustainability in technology is a key focus, with journals like *Journal of Cleaner Production*.

The topic cluster 2 (green) is named 'Marketing and Psychology' and consists of 20 journals focusing on marketing management, consumer psychology, and marketing services. Some notable journals in this cluster include the *Journal of the Academy of Marketing Science*, *Journal of Marketing*, *Journal of Marketing Research*, *Psychology & Marketing*, *Journal of Service Research*, *Journal of Services Marketing*, and *Journal of Retailing and Consumer Services*. The *Journal of Business Research* is the most representative journal in this cluster with 3,094 citations, followed by the *Journal of Marketing* (TC = 1,970) and *Computers in Human Behavior* (TC = 1,810).

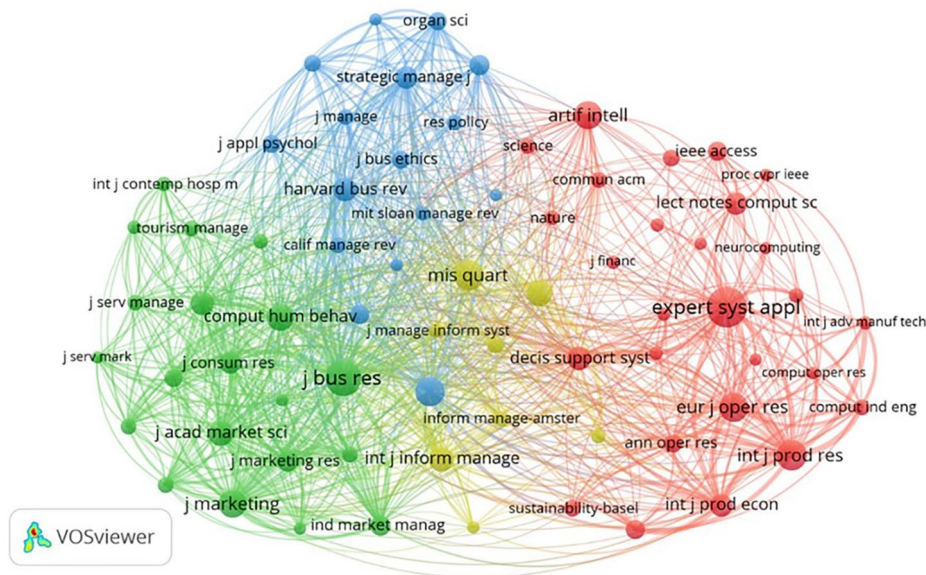
**Table 6.** Author cluster.

Cluster	Author	Publications	Avg. pub. Year	Topic
1	Bag, Surajit	9	2022.11	Artificial Intelligence; Big Data; Industry 4.0; Sustainable Manufacturing; Firm Performance; Supply Chain; User Engagement
	Choi, Tsan-Ming	5	2019.80	Artificial Intelligence; Blockchain; Industry4.0; Sales Forecasting; Operations Management
	Dwivedi, Yogesh K.	22	2021.86	Artificial Intelligence; Big Data; Supply Chains; Customer Experience; Purchase Intention
	Gupta, Shivam	12	2021.83	Artificial Intelligence; Big Data; Covid-19; Supply Chains; B2B; Firm Performance
	Kar, Arpan Kumar	6	2020.67	Artificial Intelligence; Human Resources Management; Customer Experience; Strategic Intelligence; Social Media Analytics
	Kumar, Ajay	7	2021.86	Artificial Intelligence; Big Data; Firm Performance; Decision Support; Asset Management
	Modgil, Sachin	7	2022.14	Artificial Intelligence; Supply Chain Resilience; COVID-19; Organizational Information Processing Theory; Dynamic Capabilities
	Ooi, Keng-Boon	5	2021.20	Artificial Intelligence; PLS-SEM; Para-social Interaction; Customer Experience; Corporate Privacy Responsibility
	Rahman, Muhammad Sabbir	5	2022.60	Artificial Intelligence; Marketing Analytics; Online Platform; Market Sensing; Digitalization
	Rana, Nripendra P.	7	2022.14	Artificial Intelligence; Big Data; Industry 4.0; Organization Performance; Customer Engagement;
	Sivarajah, Uthayasankar	7	2021.86	Artificial Intelligence; B2B; Crm Capability; Systems Theory; Agricultural Technology; Cloud Technologies
2	Agrawal, Rohit	5	2022.20	Artificial Intelligence; Big Data Analytics; Sustainability; Text Mining; Supply Chain;
	Dubey, Rameshwar	5	2021.20	Artificial Intelligence; Humanitarian Supply Chain; Big Data Analytics; Supply Chain Analytics; Operational Performance
	Giannakis, Mihalīs	5	2021.60	Artificial Intelligence; Big Data Analytics; Supply Chain Analytics; Social Media; User Engagement
	Gunasekaran, Angappa	9	2020.56	Artificial Intelligence; Supply Chain Management; Bibliometric Analysis; Sustainability; Digital Transformation
	Kumar, Anil	8	2021.88	Artificial Intelligence; Big Data Analytics; Text Mining; Business Strategy; Circular Economy
	Majumdar, Abhijit	5	2020.60	Artificial Intelligence; Big Data Analytics; Text Mining; Supply Chain; Circular Economy
	Ngai, Eric W. T.	8	2018.63	Artificial Intelligence; Literature Review; Supplier Selection; Decision Making; Knowledge Management
3	Grewal, Dhruv	8	2021.00	Artificial Intelligence; Privacy; Bias; Ethics; Retailing
	Guha, Abhijit	6	2021.67	Artificial Intelligence; Voice Assistants; Privacy; Bias; Ethics
	Haenlein, Michael	10	2020.10	Artificial Intelligence; Big Data; Internet of Things; Machine Learning; Robotics
	Huang, Ming-Hui	9	2020.89	Artificial Intelligence; Human Intelligence; Robots; Service Research; Human-Machine Collaboration; Feeling AI; Human Resources
	Rust, Roland T.	6	2020.67	Artificial Intelligence; Robots; Service Strategy; Machine Learning; Feeling AI
	Budhwar, Pawan	8	2022.25	Artificial Intelligence; Human Resource Management; Knowledge Sharing; Employee Experience
	Chowdhury, Soumyadeb	6	2022.00	Artificial Intelligence; Emergent Technologies; Risk Management; Human Resource Management; Supply Chain Resilience
	Kumar, Satish	6	2022.00	Artificial Intelligence; Bibliometric Analysis; Social Media; Sustainable Finance
4	Lim, Weng Marc	5	2022.00	Artificial Intelligence; Bibliometric Analysis; Education; Sustainable Finance; Ethics
	Malik, Ashish	11	2022.36	Artificial Intelligence; Human Resource Management; Employee Experience; Knowledge Sharing; Individualization
	Campbell, Colin	5	2021.60	Artificial Intelligence; Machine Learning; Social Media; Marketing Function; Customer Experience
	Kietzmann, Jan	16	2020.13	Artificial Intelligence; Machine Learning; B2B Marketing; Customer Knowledge; Sentiment Analysis
	Paschen, Jeannette	8	2020.25	Artificial Intelligence; Machine Learning; B2B Marketing; Customer Knowledge; Natural Language
5	Plangger, Kirk	8	2021.88	Artificial Intelligence; Machine Learning; Social Media; Advertising And Realities; Automated Text Analysis
	Sands, Sean	8	2021.88	Artificial Intelligence; Machine Learning; Social Media; Customer Experience; Marketing Function
	Akter, Shahriar	6	2021.50	Artificial Intelligence; E-commerce; Big Data Analytics; Market Performance; Business Analytics
	Belhadi, Amine	5	2022.20	Artificial Intelligence; Supply Chain Resilience; Sustainability; Blockchain; Cybersecurity
	Fosso Wamba, Samuel	5	2021.00	Artificial Intelligence; Literature Review; Bibliometrics; Social Innovation; Machine Ethics

(Continued)

Table 6. Continued.

Cluster	Author	Publications	Avg. pub. Year	Topic
6	Queiroz, Maciel M.	6	2021.83	Artificial Intelligence; COVID-19; Operations and Supply Chain Management; Social Innovation; Supply-Chain Resilience
	Wamba, Samuel Fosso	7	2021.71	Artificial Intelligence; Literature Review; Social Innovation; Machine Ethics; Firm Performance
	Fosso Wamba, Samuel	5	2021.00	Artificial Intelligence; Literature Review; Bibliometrics; Social Innovation; Machine Ethics
	Queiroz, Maciel M.	6	2021.83	Artificial Intelligence; COVID-19; Operations and Supply Chain Management; Social Innovation; Supply-Chain Resilience



**Figure 4.** Journal co-citation network.

Within the 'Management and Business' cluster (cluster 3, blue), *Technological Forecasting and Social Change* stands out as the most influential journal with 2,192 citations, emphasizing the implementation and longevity of emerging technologies. Other notable journals in this cluster include the *Harvard Business Review* and *Business Horizons*, with the former ranking second in influence with 1,452 citations. Additionally, the cluster encompasses various management-focused journals like the *Academy of Management Review*, *California Management Review*, and *Journal of Management*.

Topic Cluster 4 (yellow) is known as 'Information Management and Information Systems' and comprises a total of eight journals. This cluster includes prominent journals like *Information Systems Research*, *the Journal of Management Information Systems*, and *MIS Quarterly*, which is highly influential with 2,298 citations. *MIS Quarterly* emphasizes the development and application of information technology and systems. Additionally, the cluster covers Information Management topics, including journals like *Information & Management* and *the International Journal of Information Management*. *The International Journal of Information Management*, with a total citation count of 1,547, not only explores information management but also delves into information innovation within the field.

Based on the co-citation network analysis, Table 7 presents the top 10 journals with the highest total number of citations. These journals are recognized for their high impact factors, with the top 5 most influential ones being *Expert Systems with Applications* (TC = 3,768), *Journal of Business Research* (TC = 3,094), *International Journal of Production Research* (TC = 2,313), *MIS Quarterly* (TC = 2,298), and *Technological Forecasting and Social Change* (TC = 2,192). These journals hold significant authority in the research field, and aspiring scholars can explore AI publications from these sources to gain a deeper understanding of the academic forefront.

### 3.4.2. Author co-citation analysis

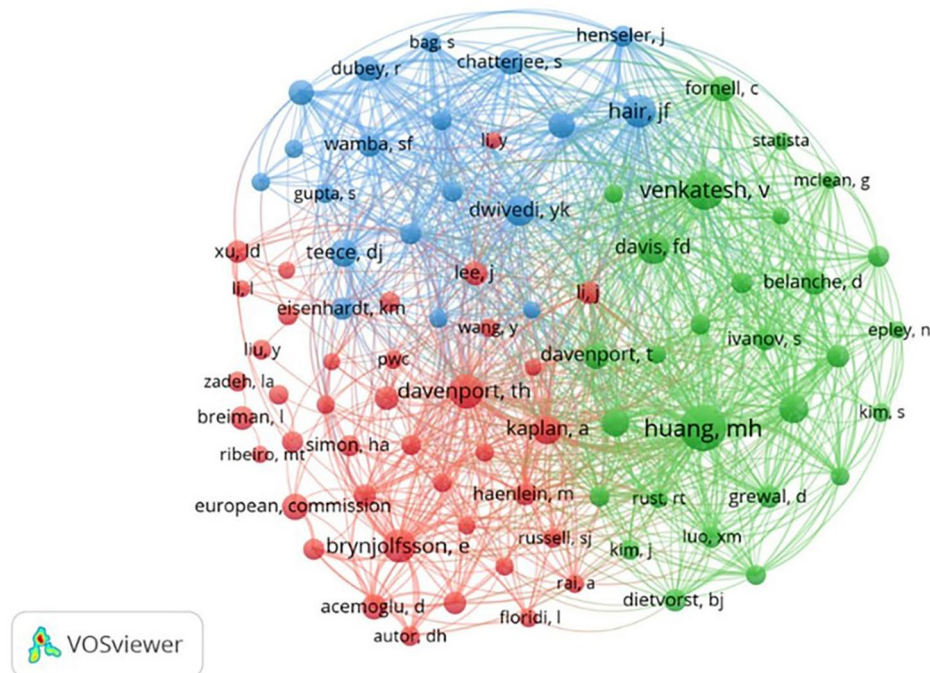
Author co-citation refers to when two authors are cited in the same paper, indicating a co-citation relationship between them. In Figure 5, an author co-citation network of 86 authors is depicted with a minimum threshold of 100. Each node in the network represents an author, with the size of the node indicating the total number of co-citations per author. The lines connecting two authors represent the co-citations between them. Additionally, Figure 5 displays three clusters identified in different colors.

The red cluster, the largest of the three clusters, consists of 39 authors. Davenport (TC = 339), Brynjolfsson (TC = 321), and Kaplan (TC = 251) are the most influential authors in this cluster. Davenport focuses on AI technology application in organizations, Brynjolfsson studies the impact of AI technology on the workforce, and Kaplan focuses on AI technology in marketing. The green cluster, with 28 authors, features Huang (TC = 572), Venkatesh (TC = 417), Davis (TC = 282), Wirtz (TC = 255), and Kumar (TC = 237) as the most co-cited authors. Huang studies the impact of AI on the service industry, Venkatesh and Davis are active in information system research, Wirtz focuses on AI in the service industry and consumer perception, and Kumar explores the impact of AI technology in marketing. The blue cluster, with 19 authors, includes Hair (TC = 305) and Dwivedi (TC = 260) as key authors. Hair focuses on Partial

**Table 7.** The top 10 journals with total citations.

Rank	Journal	TC	TLS	JCR	IF (five year)
1	Expert Systems with Applications	3768	79097	Q1	8.3
2	Journal of Business Research	3094	128241	Q1	11.5
3	International Journal of Production Research	2313	91148	Q1	8.8
4	MIS Quarterly	2298	81775	Q1	11.8
5	Technological Forecasting and Social Change	2192	58032	Q1	12
6	European Journal of Operational Research	2188	64545	Q1	6.4
7	Journal of Marketing	1970	88326	Q1	14.3
8	Computers in Human Behavior	1810	65115	Q1	10.2
9	Management Science	1733	59294	Q1	7.1
10	Journal of the Academy of Marketing Science	1561	74791	Q1	18.5

Note: TC=Total Citations; TLS=Total Link Strength; JCR=Journal Citation Report; IF=Impact Factor.



**Figure 5.** Author co-citation network.

Least squares Structural Equation Modeling, while Dwivedi delves into information systems and service attributes of AI technology applications.

Based on the co-citation network analysis presented in Table 8, the top 10 authors with the highest total citation counts are as follows: Huang (TC = 572), Venkatesh (TC = 417), Davenport (TC = 339), Brynjolfsson (TC = 321), Hair (TC = 305), Davis (TC = 282), Dwivedi (TC = 260), Wirtz (TC = 255), Kaplan (TC = 251), and Kumar (TC = 237). These authors have significantly influenced the field and have made substantial contributions to the advancement of AI.

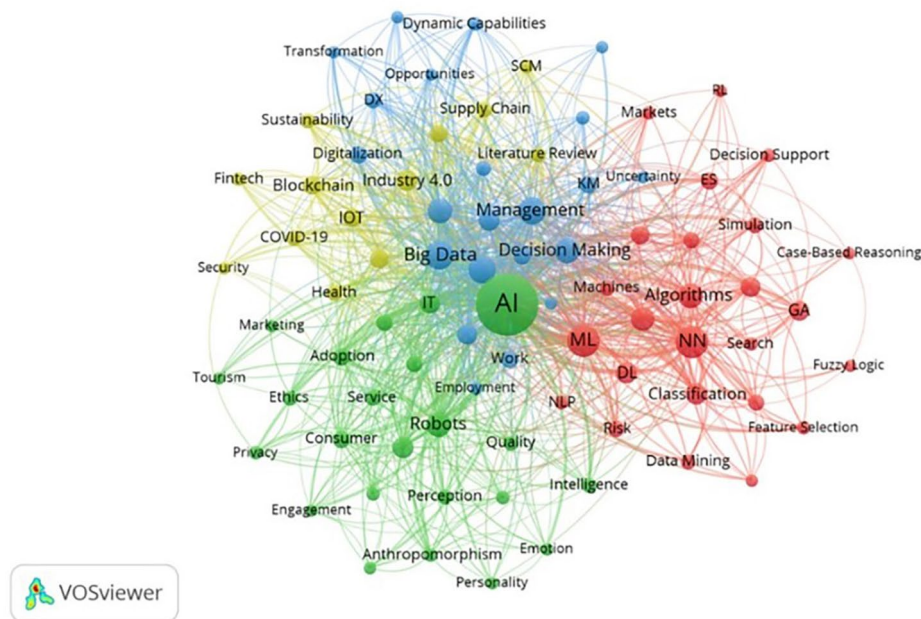
### 3.5. Keywords co-occurrence analysis

Using the keyword co-occurrence function of *VOSviewer*, we conducted an analysis of the keyword co-occurrence network based on 5,561 articles. With a keyword occurrence threshold set at 40, a total of 83 keywords were identified in the network (refer to Figure 6 and Table 9). The visualization in Figure 6 showcases the keyword co-occurrence network, revealing four distinct clusters. Node size represents the

**Table 8.** The top 10 authors with total citations.

Rank	Author	TC	TLS	Topic
1	Huang, Mh	572	5672	Artificial Intelligence; Human Intelligence; Robots; Service Research; Human-Machine Collaboration; Feeling AI; Human Resources
2	Venkatesh, V	417	3983	Machine learning; Artificial intelligence; Blockchain; Social sustainability; Supply chain sustainability; Circular economy; Industry 4.0; Internet of Things
3	Davenport, Th	339	2984	Artificial Intelligence; Robots; Automation; Organization; Trust
4	Brynjolfsson, E	321	2189	Artificial Intelligence; Information-Technology; Transparency; Internet; Digitization; Robots
5	Hair, Jf	305	3504	PLS-SEM; Partial Least Squares; Structural Equation Modeling; Circular Economy; Industry 4.0 Technologies; Supply Chain Management
6	Davis, Fd	282	2819	Information-Technology; E-Business; Information-Systems; Perceived Usefulness
7	Dwivedi, Yk	260	2998	Artificial Intelligence; Big Data; Supply Chains; Customer Experience; Purchase Intention; Knowledge Management;
8	Wirtz, J	255	2532	Artificial Intelligence; Privacy; Service Robots; Consumer Behavior; Digitization; Big Data; Social Media Content Analytics
9	Kaplan, A	251	2268	Artificial Intelligence; Big Data; Machine Learning; Robotics; Human-Machine Interaction
10	Kumar, V	237	2196	Internet of Things; Artificial Intelligence; Machine Learning; Blockchain; Robots; Marketing Strategy; Customer Relationship Management

Note: TC=Total Citations; TLS=Total Link Strength.



**Figure 6.** Keyword co-occurrence network.

Note: The keyword co-occurrence network is presented by using the VOSviewer software application.

**Table 9.** Topic clusters.

Cluster	Topic	Links	Occurrences	Avg. pub. year
1	Algorithms and applications of machine learning(red)			
	Algorithms	75	248	2017.79
	Case-Based Reasoning	22	43	2009.35
	Classification	57	161	2017.50
	Data Mining	40	72	2015.90
	Decision Support	47	60	2017.18
	DL	63	183	2021.02
	DSS	61	128	2012.62
	ES	45	115	2009.16
	Feature Selection	29	52	2018.40
	Fuzzy Logic	28	40	2013.90
	GA	48	157	2013.36
	Machines	61	79	2021.11
	Markets	54	58	2020.07
	ML	79	509	2020.51
	NLP	39	56	2019.98
	NN	74	517	2016.18
	Optimization	54	157	2016.94
	Prediction	72	238	2018.91
	Regression	31	42	2019.07
	Risk	71	91	2019.95
	RL	32	46	2017.78
	Search	50	53	2016.77
	Selection	51	83	2018.65
	Simulation	49	95	2013.53
	SVM	38	91	2016.32
2	Artificial intelligence and marketing services (green)			
	Adoption	63	99	2021.52
	AI	82	2811	2018.81
	Anthropomorphism	38	63	2021.44
	Communication	53	55	2020.45
	Consumer	64	112	2021.44
	Customer Satisfaction	38	46	2021.00
	E-Commerce	55	55	2020.71
	Emotion	49	50	2020.96
	Engagement	43	50	2021.58
	Ethics	44	67	2020.99
	Intelligence	58	70	2020.24
	IT	68	155	2020.98
	Marketing	46	43	2019.44
	Perception	52	78	2021.60
	Personality	42	41	2021.34
	Privacy	39	52	2021.35
	Quality	60	66	2020.32
	Robots	69	273	2020.83
	Service	64	90	2021.19
	Social media	69	96	2021.19
	Tourism	45	40	2020.35
	Trust	62	161	2021.37
	User Acceptance	62	90	2021.49
3	Decision making, innovation and management (blue)			
	Automation	68	146	2021.15
	Big Data	79	374	2020.95
	Business	67	76	2020.57
	Decision Making	75	256	2019.14
	Digitalization	58	102	2020.66
	DX	45	82	2020.96
	Dynamic Capabilities	39	54	2021.39
	Employment	28	40	2020.90
	Entrepreneurship	39	46	2020.83
	Evolution	46	47	2019.83
	Information Systems	50	41	2018.71
	Innovation	75	258	2021.09
	Integration	53	56	2017.52
	KM	50	103	2015.82
	Knowledge	71	183	2019.24
	Management	81	321	2020.02
	Opportunities	53	47	2021.51
	Organizations	59	98	2020.10
	Performance	81	352	2020.60
	Transformation	48	45	2021.16
	Uncertainty	54	47	2018.85
	Work	51	105	2020.86

(Continued)

**Table 9.** Continued.

Cluster	Topic	Links	Occurrences	Avg. pub. year
4	Industry 4.0 technologies(yellow)			
	Big Data Analytics	59	99	2021.57
	Blockchain	61	119	2021.11
	Covid-19	56	79	2021.71
	Fintech	47	53	2021.36
	Health	56	80	2021.35
	Industry 4.0	62	168	2021.26
	Internet	75	136	2020.62
	IoT	61	126	2020.54
	Literature Review	72	79	2021.19
	SCM	46	64	2019.75
	Security	45	45	2021.13
	Supply Chain	53	73	2020.00
	Sustainability	56	75	2021.61
Sum			12112	2019.49

Note: Avg. pub. Year = Average Publication Year, AI = Artificial Intelligence, DL = Deep Learning, DSS = Decision Support Systems, DX = Digital Transformation, ES = Expert Systems, GA = Genetic Algorithms, IoT = Internet of Things, IT = Information Technology, KM = Knowledge Management, ML = Machine Learning, NLP = Natural Language Processing, NN = Neural Networks, RL = Reinforcement Learning, SVM = Support Vector Machines, SCM = Supply Chain Management.

frequency of keyword occurrence, while the lines between nodes signify co-occurrence relationships rather than causal connections. Each cluster exhibits unique characteristics within the network.

Topic cluster 1 (red) is known as ‘Algorithms and Applications of Machine Learning’. This cluster comprises 25 keywords, with an average publication year of 2016.88, placing it in the older research field among the four clusters. It covers various common algorithms in machine learning, including genetic algorithms, deep learning, support vector machines, and neural networks. Additionally, it includes practical applications such as decision support, natural language processing, and prediction. Genetic algorithms, neural networks, support vector machines, and decision support are considered older topics within this cluster, while deep learning, natural language processing, and prediction are seen as newer. Deep learning, a concept based on artificial neural networks, has demonstrated superior performance compared to shallow machine learning models and traditional data analysis methods in many scenarios, paving the way for advancements in AI (Janiesch et al., 2021).

Topic Cluster 2 (green) focuses on ‘Artificial Intelligence and Market Services’, encompassing 23 keywords. The cluster explores the utilization of AI technology in various business sectors like robots, social media, e-commerce, and marketing. Notably, robots feature prominently in discussions, particularly in the context of hotel and tourism management and broader service industries (Shin, 2022). Ethical considerations surrounding AI, including ethics, trust, and privacy, are key areas of interest within this cluster. Of these, trust and privacy, are emerging topics. While AI advancements offer substantial advantages to organizations, the rapid expansion of AI presents notable challenges related to data security and privacy (Villegas-Ch & García-Ortiz, 2023). Future endeavors in AI technology must prioritize safeguarding user privacy and enhancing consumer trust. Despite the increasing implementation of robots in customer service by businesses, concerns persist regarding consumer trust and acceptance (Prakash et al., 2023). Governments play a crucial role in addressing data privacy and security concerns in AI applications to ensure that AI services enhance convenience and efficiency in citizens’ lives (Kankanhalli et al., 2019). Additionally, this cluster delves into the consumer experience within AI applications, examining aspects like customer satisfaction and user acceptance. Overall, the cluster represents a relatively new area of study, with an average publication age of 2020.89.

Topic Cluster 3 (blue) focuses on ‘Decision making, Innovation, and Management’, encompassing 22 keywords with an average publication year of 2020.08. Representative terms include decision making, innovation, performance, and knowledge management, all crucial in business organizations. While knowledge management and decision making are considered more established topics, innovation and performance are seen as more recent. Research by Mikalef and Gupta (2021) highlights the benefits AI technology can bring to organizational innovation and performance, with AI capabilities further enhancing organizational innovation. Additionally, the cluster explores big data and automation technologies. Big data is seen as a valuable resource for enterprises, driving innovation in AI and enabling efficient business operations through data analysis. Automation, particularly in the service sector, is shown to boost productivity and mitigate production risks (Meyer et al., 2020).

### 3.6. Overlay visualization of keywords over time



**Figure 7.** Temporal mapping of Keywords.

Around 2019, the application of AI technology in enterprises became increasingly widespread, encompassing terms like supply chain management, IoT, Internet, digitalization, robot, and big data. By 2020, with the advancement of scientific and technological innovation, new terms such as e-commerce, tourism, management, performance, markets, marketing, decision making, and emotion signified the broad utilization of AI in management, business science, and applied psychology. Moving into 2021, keywords like trust, security, and privacy indicate a growing concern among researchers and practitioners regarding safeguarding privacy, data security, and other security issues in the face of expanding AI technology and data generation. Additionally, sustainability and novel coronavirus pneumonia emerge as focal points for scholars during this period. Finally, in 2022, the appearance of keywords like explainable AI, financial performance, and voice assistants reflects the emergence of interpretable artificial intelligence aimed at enhancing user understanding and utilization of AI technology across various domains such as intelligent assistants and finance to support informed decision-making.

## 4. Discussion

### 4.1. Contribution

Our research aims to conduct a thorough and systematic review of AI research in the domains of management, business, and applied psychology using bibliometric methods. This analysis seeks to provide insights into the current state of the field's performance and intellectual structure for both researchers and practitioners. By examining 5,561 articles from the Web of Science Core Collection database, we explore various aspects such as the focus of current AI research, top journals, countries, authors, and institutions, influential studies, author collaboration networks, key authors and journals, keyword co-occurrence, and the contextual development of AI research. Through this study, we contribute to four key areas.

First of all, this paper provides an in-depth analysis and an overview for researchers to understand the latest research status of AI in the fields of management, business, and applied psychology. It is different from previous quantitative analyses of AI research focusing on a specific field (Arsenyan & Piepenbrink, 2024;; Mariani et al., 2023), as this study analyzed 5,561 articles related to AI in the fields of management, business, and applied psychology from the Web of Science Core Collection database, and revealed the overall picture of research on AI and enterprise organizations. Specifically, our research: (1) analyzed journals (Table 1), authors (Table 2), countries (Table 3), and institutions (Table 4) contribute most to AI research in management, business, and applied psychology, as well as what are the iconic and influential studies (Table 5). (2) Discovered the most influential journals in the fields of management, business and applied psychology (Table 7 and Figure 4). (3) Identified the core and most influential authors of AI research in the fields of management, business, and applied psychology (Table 8 and Figure 5). (4) Revealed the knowledge structure of AI research in management, business, and applied psychology (Table 9 and Figure 6).

Second, this study delves into the knowledge structure of AI research within the realms of business, management, and applied psychology, enhancing researchers' comprehension of the current landscape of AI research. The findings suggest that current AI research can be categorized into four clusters: algorithms and applications of machine learning, AI and market services, decision making, innovation and management, and Industry 4.0 technologies. The first cluster encompasses fundamental AI technologies like fuzzy logic, genetic algorithms, machine learning, and neural networks, serving as the foundation for AI implementation across various sectors. The second cluster explores AI's role in market services, including consumer services, e-commerce, and robotics. The third cluster focuses on decision making, innovation, and management in relation to big data analysis, digital transformation, and information systems. Lastly, the Industry 4.0 technologies cluster covers technologies pertinent to Industry 4.0 and their practical applications, such as blockchain, cloud computing, Industrial Internet of Things, and simulation technologies.

In addition, AI, as a rapidly evolving field, has gained significant attention in recent years due to its interdisciplinary nature. Through our analysis of the AI knowledge graph, researchers have the opportunity to transcend traditional research boundaries and foster collaboration between diverse areas of study.

For instance, by integrating AI, industry 4.0, and deep learning, researchers can explore new avenues of research. Our examination of the knowledge structure of AI in business, management, and applied psychology offers a comprehensive foundation and roadmap for researchers looking to engage in interdisciplinary research.

Third, by discovering the evolution of different research topics related to AI in the fields of management, business, and applied psychology, we identify several new trends in future AI research and contribute to the future direction of academic development. Our analysis of keyword average years of publication and overlay visualizations shed light on the trajectory and trends of different research topics. We found that expert systems and case-based reasoning studies (e.g. Choy & Lee, 2003; Ruiz-Mezcua et al., 2011) were the early focus of researchers in management, business, and applied psychology. Later, researchers shifted their focus to topics such as genetic algorithms, data mining, neural networks, support vector machines, deep learning, and integrated applications of AI (e.g. Fu et al., 2013; Stefanovic, 2015; Zafeiriou & Kalles, 2013; Li et al., 2015; Bathla et al., 2019). Researchers then shifted their focus to current topics such as perception, personality, big data analytics, sustainability, privacy, Industry 4.0, and explainable AI (e.g. Alsubhi et al., 2023; Hoffman et al., 2022; Hu & Min, 2023; Panța & Popescu, 2023; Rosário & Dias, 2022; Yigitcanlar et al., 2023). This shows that the focus of researchers in the fields of management, business, and applied psychology has gradually shifted to issues such as human cognition and behavioral ability in the application of AI in Industry 4.0, as well as sustainable development, which is also the trend of AI research and application. Furthermore, our research highlights a rising emphasis among researchers and practitioners on data security, privacy, and trust, despite the widespread applicability and utility of AI across various industries.

#### **4.2 Limitations and future research**

Like all studies, our research has limitations that must be acknowledged. Firstly, we only collected literature from the Web of Science database, potentially missing AI literature not indexed in WOS. Therefore, researchers should interpret our findings in the context of our sample. In the future, expanding the search to include more databases like Scopus could enhance the scope. Secondly, while our study provides valuable insights into the research landscape and evolution of AI in management, business, and applied psychology, our bibliometric approach did not allow for detailed analysis of domain-specific topics within these fields. This highlights the need for future research to delve deeper into these areas. Lastly, as our study is exploratory and based on bibliometric methods, future research designs, such as meta-analyses, are necessary to provide more conclusive results.

### **5. Conclusion**

AI is increasingly being applied in organizations, making it a current research focus. However, there is a lack of comprehensive bibliometric studies to uncover the current state and future trends of AI research in these fields. This study aims to fill this gap by analyzing AI publications from the Web of Science database in management, business, and applied psychology. The visualization tool *VOSviewer* was used to identify influential journals, authors, and publications, and to analyze author cooperation, co-citation, and keyword co-occurrence networks. These analyses not only illuminate the fundamental topics but also identify the research directions of AI research. Our findings suggest that researchers can focus on human cognition, behavioral ability, data security, privacy, trust, customer service, social media, big data analytics, fintech, health, dynamic capabilities, and sustainable development, which are the emerging trends in AI research and application across various industries. Overall, building on these findings, the study proposes future research agendas, providing scholars with a systematic understanding of the current research landscape and its evolving trends.

#### **Note**

1. Information was retrieved from (accessed June 2, 2023): <http://www.isiwebofknowledge.com>.

## Author contributions

Yangjie Lai was involved in analysis and interpretation of the data, and the drafting of the paper. Peng Liu was involved in the conception and design. Dege Liu contributed to critical revision of the drafting of the paper.

The authors ensure that all listed authors meet the criteria for authorship as per the ICMJE guidelines. All authors agree to be accountable for all aspects of the work, and all authors approved the final manuscript and published version.

## Disclosure statement

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## Data availability statement

The Data generated during the current study are available from the corresponding author (Dege Liu) on reasonable request.

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