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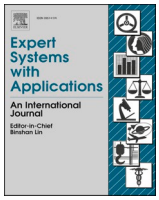

Knowledge evolutionary process of Artificial intelligence in E-commerce: Main path analysis and science mapping analysis

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ABSTRACT

Artificial intelligence (AI) is the latest designing and interacting technology used to support organizations in the competitive electronic commerce (E-commerce) context. The studies on AI in E-commerce remain fragmentary since few papers review the evolutionary process of knowledge infrastructure. To bridge this gap, we constructed a conceptual framework from the resource orchestration perspective, and retrieved 2252 documents from the Web of Science (WoS) database dating from 1998 to 2022 to synthesize the extant research on AI in E-commerce. Specifically, we integrated main path analysis with science mapping analysis covering the strategic diagram and evolution map. Through qualitative analysis of critical nodes in main paths, this article found that knowledge disseminated around recommender systems (RSs). This article also examined the performance traits and inter-relationships of significant themes over three consecutive time zones, as well as identified four main AI-enabled outcomes (thematic areas): *Optimization and decision support*, *Trust and personalized recommendation*, *Sentiment analysis,* and *AI theories with allied technologies*. Potential research prospects and implications are proposed based on these findings. Overall, this article provides state-of-the-art information on how AI can facilitate the implementation of E-commerce operations and could serve as a stepping stone to newcomers in the scientific community.

1. Introduction

Electronic commerce (E-commerce) refers to a business model permitting governments, businesses, and individuals to engage in activities related to trading over the internet via applying certain technologies to exchange information and manage knowledge facilitating activities within and across value chains, as well as decision-making processes underpinning these tasks (Holsapple & Singh, 2000). Artificial intelligence (AI) is the most representative of such technologies. By accurately analyzing complex and ambiguous external information, making sense of such data, and leveraging those lessons to accomplish business goals (Kaplan & Haenlein, 2019), it has driven the intelligent development of E-commerce companies. Depending on specific application scenarios, AI could be conceived as a system, an algorithm, or a paradigm (Bawack et al., 2022). In the actual scenario, artificial knowledge increases accountability and sustainable performance (Di Vaio et al., 2023b); improves purchasing capacity and process integration (Ordanini & Rubera, 2008); provides consumers with personalized and convenient service, especially enhancing interactivity by voice assistants and virtual reality (Chandra et al., 2022; Glikson & Woolley, 2020). Also, a mature cross-border E-commerce ecosystem contributes to establishing a high level of trust and partnerships (Qi et al., 2020) and even alleviating the pressure brought by deglobalization and the COVID-19 pandemic (Zhang & Yuan, 2021).

Over the past two decades, large numbers of relevant articles have been published in interdisciplinary academic journals, both from the lens of consumers (Li et al., 2022; Wang et al., 2021) and organizations (Zhang et al., 2021; Kamble et al., 2021). Faced with the explosive growth of the scattered publications, many scholars have attempted to summarize the development of this domain, which facilitates interested researchers to obtain a thorough understanding of the knowledge structure in a given field (Martin, 2012). This article examined the differences between ours and prior reviews in foci, data scale, time span, method, and contributions, which are listed in Table 1. Despite that researchers provide insights from different angles, no systematical and comprehensive overviews retrospect the evolutionary process of knowledge infrastructure, particularly on the transmission trajectories and conceptual structure. It is difficult for academics and practitioners to

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evaluate the extent to which the existing literature concerns relevant issues or addresses pertinent studies' gaps due to the absence of synthesis and analysis.

As such, it is necessary to make an overview focusing on theme evolution and knowledge transmission. Occasionally, researchers utilize citation network analysis and co-word analysis (Garfield, 1994) to longitudinally monitor the progress of an academic domain over successive time periods, which is conductive to broadening the train of thought, deciphering and tracking scientific knowledge in turn (Donthu et al., 2021; Chen et al., 2022; Yu et al., 2021a; Yu et al., 2022; Zhang et al., 2023). In light of this, this study established a conceptual framework based on resource orchestration theory and integrated main path analysis with science mapping analysis to encapsulate the extant literature on AI in E-commerce. Specifically, based on the constructed citation network from global approaches, this article first described milestone papers to illustrate the knowledge transmission in the main paths. Then, this study uncovered hidden themes, and their evolutions, as well as extracts four thematical arenas subjectively through science mapping analysis.

This article's results show that the academic research on AI in E-commerce revolved around recommender systems (RSs) to advance knowledge dissemination. The main thematical arenas are *Optimization and decision support*, *Trust and personalized recommendation*, *Sentiment analysis,* and *AI theories with allied technologies*. The results contribute to answering debates regarding the emerging challenges and opportunities (Dwivedi et al., 2021) and advancing the agenda for research and practice of applying AI in the E-commerce landscape (Manser Payne et al., 2021). Considering that offering theoretical background is necessary for understanding, elucidating, or learning from complicated phenomena (Cram et al., 2020), synthesizing the extant literature about AI in E-commerce is fundamental to advancing this domain, especially beneficial in proposing novel theories and applications.

The remaining parts are organized as follows: Sections 2 and 3 expound the theoretical foundation and research methods of this article. Section 4 describes the data source and conducts statistical analysis, and Section 5 is divided into two subsections, revealing important document junctures, hidden themes, and corresponding thematical areas, with a discussion about research results, prospects, and implications situated within Section 6. Finally, Section 7 summarizes the content, findings, contributions, and limitations of this research.

2. Theoretical background

2.1. AI in E-commerce

AI focuses on the study of human intelligence phenomena and the development of computer systems capable of emulating human behavioral patterns and generating problem-solving knowledge (Min, 2010). Holding the promise of surmounting the cognitive and physical boundaries of humans (Daugherty &Wilson, 2018), it unlocks a plethora of application possibilities, especially in enhancing the performance and productivity of organizations (Dwivedi et al., 2019). The anticipated business benefits encompass optimizing decision-making and internal business processes, refining and innovating existing products or services, liberating employees for more creative tasks, and expanding into new markets (Davenport & Ronanki, 2018).

AI in E-commerce inherently refers to adopting AI systems, tools, techniques, or algorithms to support business activities associated with the online purchase and sale of products or services (Bawack et al., 2022). It is reshaping E-commerce by correctly comprehending and interpreting external information, acquiring knowledge from such data, and applying these insights to accomplish particular goals through flexible adjustments (Kaplan & Haenlein, 2019).

The latent advantages of implementing AI in E-commerce have been substantiated. For example, Chen et al. (2022) examined the impact of technical advantages benefit from AI on firm performance, including the rate of market share expansion, the introduction of novel products or services, and the likelihood of encountering financial difficulties. Empirical results indicated that the contribution of building, integrating, and utilizing AI-related resources is positively correlated with firm performances, thereby supporting E-commerce companies in achieving competitive advantages. Di Vaio et al. (2023b) demonstrated artificial knowledge and digitalization drive transformation in supply chain management by increasing accountability and sustainable performance. Thus, integrating AI-related resources into the enterprise business model is regarded as an effective strategy for rising to the challenges associated with rapidly changing customer demand and stiff homogeneous competition.

However, many individual organizations are currently grappling with one formidable task which is adapting their business models to ensure alignment between AI and organizational goals from a strategic

Table 1
Comparative studies between previous reviews and our work.

Review	Focus	Time span	Data scale	Method	Contribution
Akter and Wamba (2016)	Big data analytics (BDA)	2014	48	(1) Content analysis	(1) Explore the definition, features, value, types, etc., in the context of BDA in E-commerce. (2) Discuss potential opportunities and challenges in research and practice ahead.
Nosratabadi et al. (2020)	Machine learning and Deep learning methods	2013–2019	217	(1) PRISMA model	(1) Present the taxonomy of data science methods and applications in economics. (2) Review how data science has contributed to economic-related domains.
Chandra et al. (2022)	Personalized marketing	1990–2021	383	(1) Performance analysis (2) Science mapping analysis	(1) Provide the first comprehensive review of personalized marketing. (2) Point out limitations and future directions.
Almahmood and Tekerek (2022)	RSs	/	/	(1) Content analysis (2) Statistical analysis	(1) Examine deep learning tools employed to design RSs in E-commerce. (2) Identify problems and corresponding solutions to RSs.
Bawack et al. (2022)	Whole area	1975–2020	4335	(1) Content analysis (2) Bibliometric analysis	(1) Synthesize AI-related literature in E-commerce. (2) Propose the possible contribution approaches of information systems research to this domain.
Our work	Whole area	1998–2022	2252	(1) Content analysis (2) Science mapping analysis (3) Main path analysis	(1) Delineate the mainstream knowledge flow trajectories. (2) Uncover hidden thematic clusters, their characteristics, interrelationships, and thematical areas. (3) Present the starting point, status quo, and prospects, as well as give some suggestions and guidance for future scholars and practitioners.

and operational perspective to drive transformative changes with far-reaching implications for the economic and social fabric. Indeed, there are still many challenges when it comes to applying AI-related resources in e-business practices. In terms of online retail sales gains, many E-commerce companies have not lived up to expectations primarily because managers often struggle with effectively integrating AI with existing processes and systems. Thus, it is necessary to conduct more synthesizing research on AI in E-commerce to provide the background to describe, comprehend, or decipher phenomena, and to inform academic and technical orientations in this research area (Cram et al.,2020).

2.2. Resource orchestration perspective

Resource-based theory (RBT) provides a managerial framework that supports business organizations in identifying strategic resources that could be leveraged to achieve and maintain competitive advantages (Wernerfelt, 1984; Bag et al., 2021). In light of RBT, Sirmon et al. (2011) proposed the resource orchestration perspective to elucidate how a company achieves competitive advantages by dynamically allocating and organizing its resources. There are two main research streams. One stream center around the influence of resource orchestration on outcomes, such as innovation (Cui et al., 2017), performance (Wales et al., 2013), and value creation (Wang et al., 2012). The other stream aims to determine resource-focused activities in distinct contexts (Pan et al., 2020).

Based on RBT, AI-related resources are increasingly deemed as pivotal and intangible assets for advancing business performance (Lou & Wu, 2021), and may provide businesses with competitive advantages (Chaudhuri et al., 2021). Meanwhile, the capabilities related to organizing AI in E-commerce are also seen as particularly valuable from the resource orchestration perspective. The efficient and effective implementation needs significant infrastructural resources (Chatterjee et al., 2021), containing technical support, software and hardware devices, and data resources. Most of the businesses of E-commerce firms are carried out online, which gives them a natural advantage in accessing data resources (Wang & Fan, 2021). Although possessing this advantage, the proclivity of companies to orchestrate AI is more crucial (Denicolai et al., 2021).

As inllustrated in Fig. 1, the resource orchestration framework forms the theoretical foundation of this article, aiming to identify crucial resources associated with AI in the context of E-commerce, as well as the corresponding orchestration operations and resulting AI-enabled outcomes. This aligns with the recommendations of AI management researchers, emphasizing that E-commerce organizations should utilize resource collections and develop appropriate capabilities when integrating AI (Davenport & Ronanki, 2018). The resource orchestration perspective is also applicable to the study of E-commerce, which is typically defined as a business model involving a combination of resources and processes (Pan et al., 2021). Therefore, we complement the extant reviews by constructing co-word and citation networks to investigate AI in E-commerce and address four specific research questions (RQs) as follows:

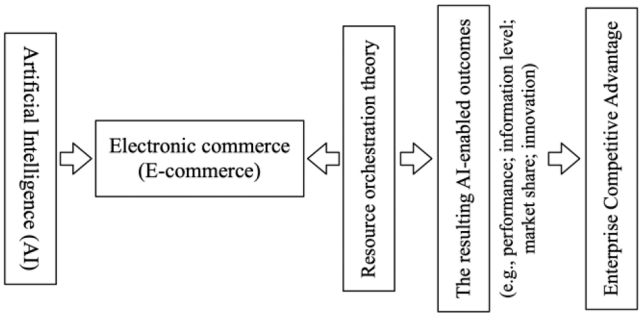


Fig. 1. The theoretical framework of AI in E-commerce from the resource orchestration perspective.

RQ1. As involving the development of many areas/disciplines, what do we know of AI in E-commerce? Specifically, which journals, papers, and authors played a key role? What is the starting point, focus, and current state of its research?
RQ2. Which AI-related resources will support E-commerce companies in cultivating competitive advantages?
RQ3. Compared with existing studies, is there a better and more objective approach to investigating this domain?

3. Methodology

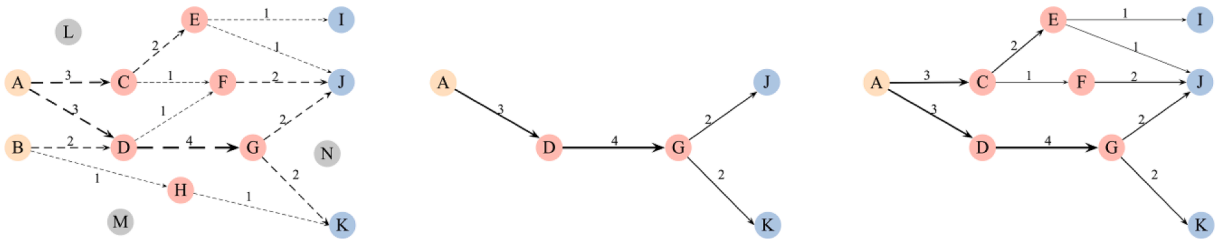
3.1. Main path analysis

This section will briefly expound on the theoretical background and principles of main path analysis. In a citation network consisting of numerous documents, academic papers are regarded as nodes, and the connections among them serve as conduits for knowledge movement. There are four categories of nodes: sources, intermediates, sinks, and isolates. Sources refer to seminal nodes cited while citing no others; intermediates cite other works and are simultaneously cited; sinks are considered as nodes that cited others but are not cited; isolated nodes bear no citation relationships to other works (Liu et al., 2013). It is undoubtedly interpreted that papers in the main path are important in disseminating knowledge, and nodes situated upstream are more impactful than those located downstream since all subsequent ideas originate from them.

Main path analysis is originally introduced by Hummon and Dereian (1989) and has two steps to be operated. First, calculate the traversal value of each route based on its respective contribution in the constructed citation network; that is, using social network terminology, assigning weight to a non-weighted directed network. To this end, Hummon and Dereian (1989) devised three traversal count algorithms: search path link count (SPLC), search path node pair (SPNP), and node pair projection count (NPPC). More than a decade afterward, Batagelj (2003) proposed another efficient connectivity measure—search path count (SPC), which carries an interesting property that, for any node except the sources and sinks, the sum of SPCs of the inward links is equal to that of the outward links. The above traversal algorithms all assume the citation network is acyclic, and this prerequisite must be met when adopting the main path analysis. Rather than discussing the advantages and disadvantages of these algorithms, this article just referred to the recommendation of Batagelj (2003) and employed SPC to obtain citation link weights.

Second, extract the main path based on the size of traversal values. Hummon and Dereian (1989) developed “priority first search algorithm” to determine the forward local main path. Further, Liu and Lu (2012) proposed several novel link selection techniques, such as the global main path and the key-route global main path from the lens of the global structure of a citation network. It is worth noting that different link selection techniques can extract the main path with different preferences, thereby emphasizing knowledge transmission trajectories from diverse perspectives and complementing one another. To gain more insights into AI in E-commerce from a satellite perspective, we compared the differences among the results that applied different types of search algorithms. Specifically, focusing on emphasizing the overall importance of intellectual diffusion, in addition to elaborating the most significant path by global main path analysis, this study explored several routes with lower overall SPC counts than the most predominant one by conducting key-route global main path analysis. By integrating these paths, the kaleidoscope was turned on and enhanced the possibilities of uncovering more critical avenues from a multidisciplinary angle.

We take Fig. 2 as a simple citation network example. Fig. 2(a) has two source nodes, A and B, three terminal nodes, I, J, and K, and three isolated points, L, M, and N, remaining for intermediates. Different



(a) A simple SPC weighted citation network (b) The global main path (c) The key-route global main path

Fig. 2. Main path based on the same citation network and different search algorithms.

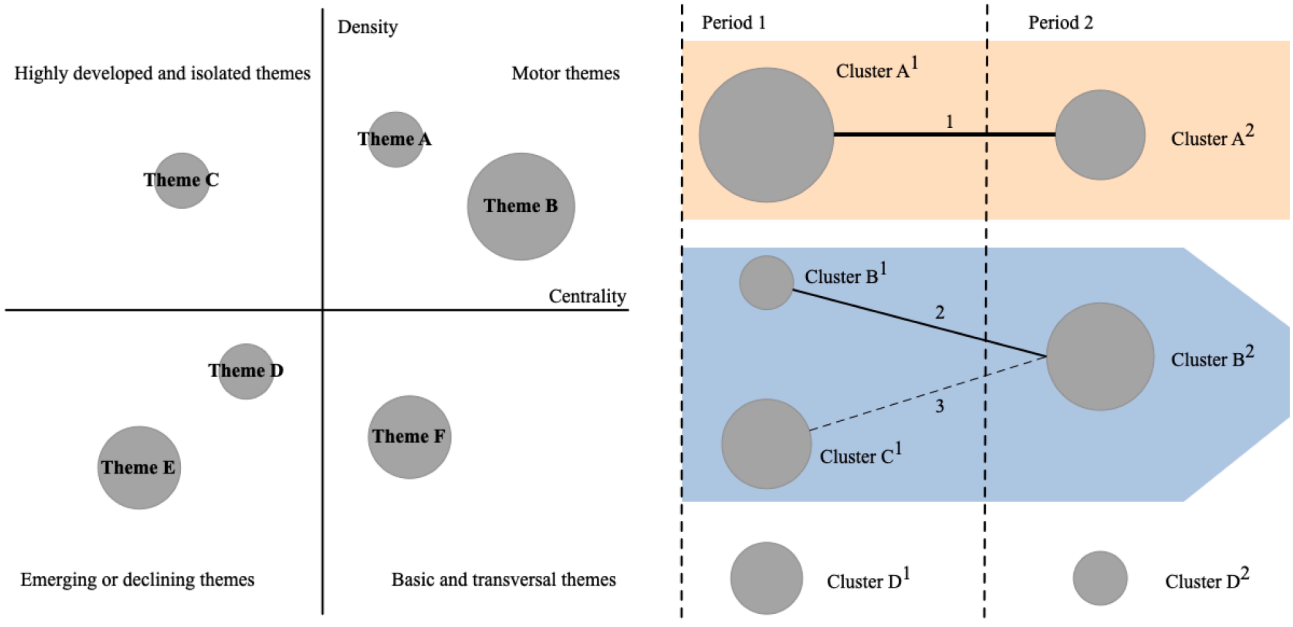
colors represent different node types. The SPC value of each route is measured by calculating how many times it is passed from every source to each terminal node (Xiao et al., 2014). For example, the SPC of G-K is two since the link has been passed through twice, via A-D-G-K and B-D-G-K. Liu and Lu (2012) defined the global main path in global structure as the trajectories with the highest overall weight, and the decimation results are illustrated in Fig. 2(b), since the paths with maximum value are A-D-G-J and A-D-G-K. Instead of simply tracing forward from starting nodes to terminal nodes, Lu and Liu (2013) proposed a search procedure for ensuring the largest traversal count included in the main path. For example, three links A-C, A-D, and D-G will be uncovered if opt the top two SPCs. Then, applying the global method, search forward and backward from the head and tail node of the target route, respectively, namely A-C-E-I, A-C-E-J, and A-C-F-J are determined from the connection A-C, and A-D-G-J and A-D-G-K are determined from routes A-D and D-G. Finally, putting together the results, A-C-E-I, A-C-E-J, A-C-F-J, A-D-G-J, and A-D-G-K are the key-route main path delineated in Fig. 2(c). Different traversal algorithms may produce the same results in this example, but the probability of this happening in practice applications is very low (Xu et al., 2020).

3.2. Science mapping analysis

Bibliometric mapping focuses on tracking the evolution of certain scientific fields to ascertain their cognitive structure formed in the longitudinal development process (Noyons et al., 1999). Many researchers utilized this method to dynamically reveal hidden important disciplinary components (Tobon et al., 2020; Yu et al., 2021b; Yu and Hong, 2022; Yu et al., 2023).

Many relevant software tools are developed for bibliometrics research (Cobo et al., 2011b). We chose the open-source software SciMAT to perform an in-depth investigation (Cobo et al., 2012). To our knowledge, various techniques are also available for establishing a science map (Small, 2006). Co-word analysis is one of the illustrated techniques to construct multiple semantic networks that underline associations between keywords, and where associations may exist (Krsul, 1998). In the configure wizard, we chose the "equivalence index" to determine similarities between keywords (Callon et al., 1991) and the "simple center algorithm" to cluster key terms to themes (Coulter et al., 1998). This article also carried out the performance analysis using bibliometric indicators, laid out the clusters in the strategic diagram, and detected the main thematical areas by conceptual evolution map (Callon et al., 1991).

The strategic diagram is defined as a low-dimension cross-categorization coordinate system of themes based on centrality and density. Thereinto, centrality refers to the level of network interaction with others, which is equivalent to the external strength of a thematical cluster, assisting analysts in gauging its significance in global development. Density describes the internal cohesion of different links within a cluster, which permits analysts to assess the clusters' maturity (Paule-Vianez et al., 2020). As delineated in Fig. 3(a), the x-axis represents centrality, and the y-axis represents density. Four categories emerge in



(a) The strategic diagram (b) The evolution map

Fig. 3. Schematic diagram of science mapping analysis.

the strategic diagrams: (1) themes in the first quadrant with higher centrality and density contribute greatly to the cognitive structure; as such, they are called the motor themes; (2) themes located in the second quadrant with high density and low centrality are characterized by specialized and insular; (3) third quadrant themes are neither developed nor given sufficient attention, usually denoting themes that are vanishing or emerging; (4) themes situated in the fourth quadrant are basic and transversal, indicating their importance to this academic field and potential for further development.

The conceptual evolution map helps analysts to roughly pinpoint the "backbones" of the given research field, along with their genesis and inter-relationships. Cobo et al. (2011a) proposed the "thematic nexus": a linkage will be created from one cluster to another if the same terms simultaneously appear in two adjacent thematic networks. It is therefore possible to construct the evolution map for the study domain by dividing it into successive phases. Furthermore, we employed the "inclusion index" (Eck & Waltman, 2009) to estimate the extent of overlap between clusters. Fig. 3(b) illustrates a scientometric map covering two stages with different colors indicating two distinct thematic arenas. The solid lines represent that the connected clusters possess the name: either the same keywords label the themes, or one term's label is part of the content of another. The dotted line indicates that the clusters have similar elements apart from their names (Cobo et al., 2011a). Each sphere's volume is displayed in proportion to its h-index index, while the thickness of every line is proportional to the inclusion value. Cluster D^2 occurs as a fresh cluster in the next stage as no clusters connect, indicating that the themes within Cluster D^1 have gradually waned.

4. Data

This data sample was derived from the Web of Science (WoS) core collection for literature published between 1998 and 2022. WoS was selected for its lower duplicate bibliometric records rate (Aghaei Chadegani et al., 2013) and border coverage of high-impact scientific journals (Aria et al., 2020). To improve the credibility of this research, we extracted relevant recordings from Science Citation Index Expanded (SCIE) and Social Sciences Citation Index (SSCI). The following set of keywords were entered in the database retrieval, in pseudo-code: Topic Search (TS) = ("Artificial intelligence" OR "case-based reasoning" OR "Artificial neural network" OR "cognitive computing" OR "computer vision" OR "cognitive science" OR "data mining" OR "speech recognition" OR "text mining" OR "deep learning" OR "data science" OR "fuzzy logic" OR "fuzzy linguistic modelling" OR "image recognition" OR "genetic algorithm" OR "neural network" OR "k-means" OR "machine vision" OR "machine learning" OR "logic programming" OR "natural language processing" OR "pattern recognition" OR "knowledge-based system" OR "expert system" OR "recommender system" OR "recommendation system" OR "support vector machine" OR "SVM" OR "semantic network") AND ("Electronic Commerce" OR "e-commerce" OR "ecommerce" OR "Electronic business" OR "e-business" OR "ebusiness" OR "online shopping" OR "Internet Commerce" OR "online purchase" OR "online store" OR "internet shopping" OR "electronic shopping" OR "e-purchase"). It stems from prior rigorous work by Bawack et al. (2022) and limits bibliometric material to issues of AI-related definitions and techniques in E-commerce. To maintain a higher level of quality, we only considered documents classified as article and review, which are deemed to experience a peer-review process before being published (Milian et al., 2019). As of October 31, 2022, an overall number of 2252 documents have been collected to conduct further analysis, including 2120 articles and 132 reviews, constructed by 5910 authors and 76,991 references. The specific search strategy is illustrated in Fig. 4.

Generally, the annual number of publications suggests growth in this field, and the overall number of citations obtained is a more precise measure of impact (Panaretos & Malesios, 2009). Since citation counts may be deflated due to the time lag effect or inflated by several "big hits", Hirsch (2005) proposed the h-index to better quantify the broad impact of a scientific field. Fig. 5 synthetically illustrates the above indicators and delineates the annual distribution of literature among the three most prolific countries.

The number of scholarly publications on AI in E-commerce has continued to rise yearly since the first publication appeared at the end of the 20th century. It was on introducing an adaptative system for creating

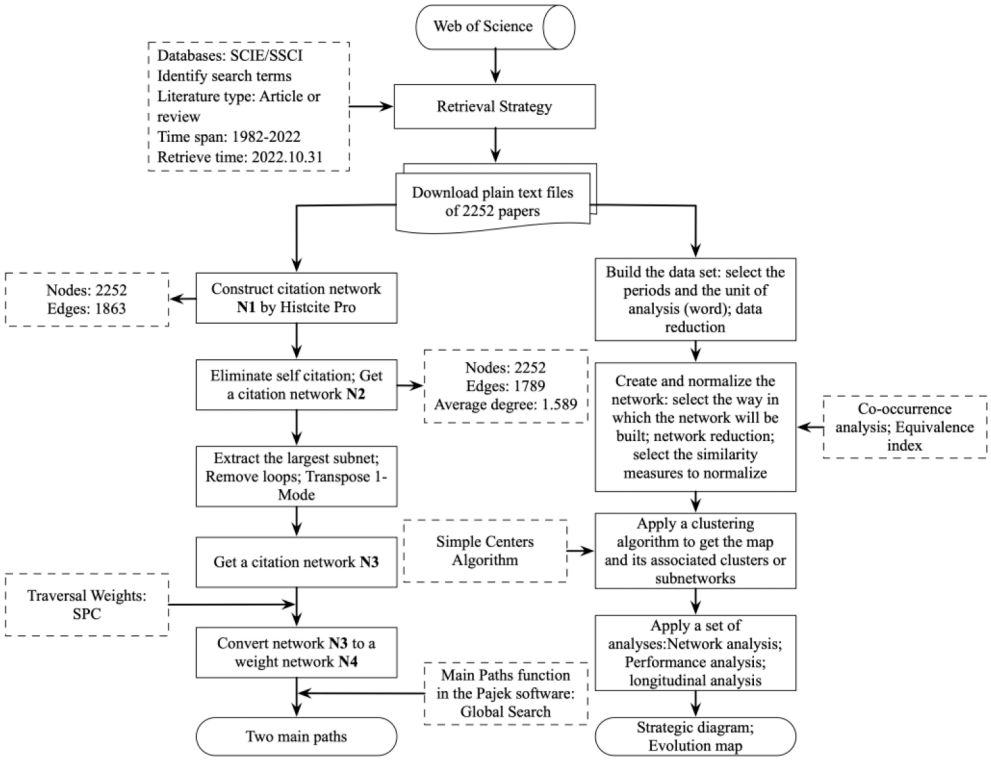


Fig. 4. Data processing and analysis procedure.

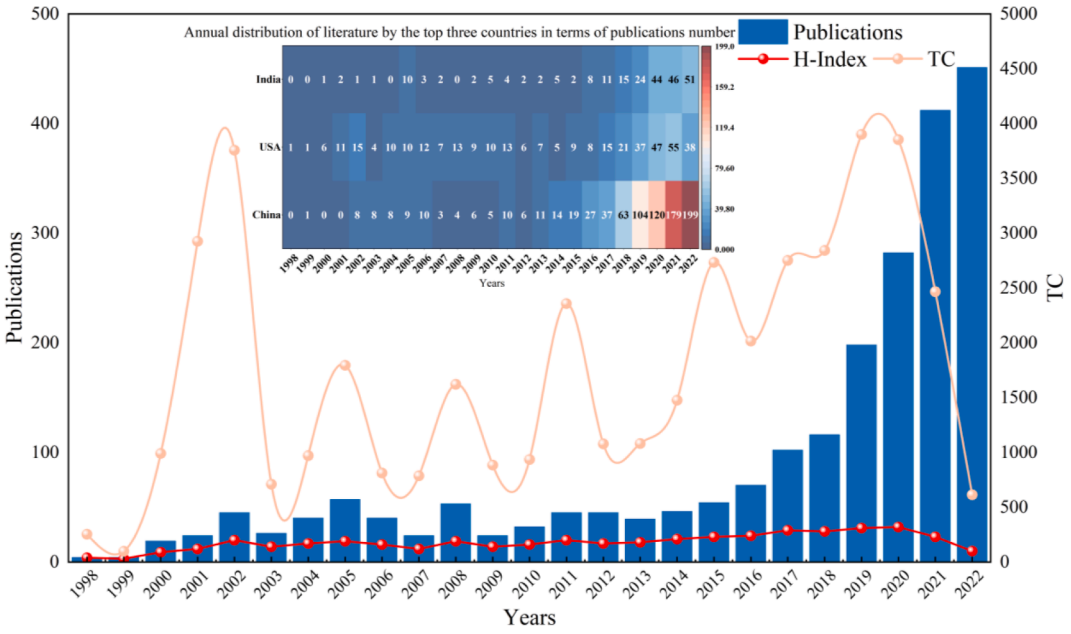


Fig. 5. General statistical analysis of AI in E-commerce.

multimedia presentations in electronic shopping by using an incremental learning algorithm to efficiently recognize consumer preferences (Joerding & Meissner, 1998). From the perspective of yearly citation counts and h-index, the former presented a dramatic fluctuation and reached its maximum in 2019 with 3901 overall citations; while, the latter curve was relatively stable, keeping around 18. Regarding the national distribution of documents, China, the USA, and India ranked in the top three. In that, China researchers authored the most papers, with a total of 851, representing nearly 38 % of all. Considering that the COVID-19 pandemic has pushed forward the global practice process of cross-border E-commerce, scholars actively conduct applied research to develop more suitable and efficient AI solutions in this interaction within their respective national context.

Combining the above analysis and the scientific change theory of Kuhn (1962) and Shneider (2009), this field has already been in the third stage and evolved towards the fourth. A comprehensive overview is needed for the next stage to deliver the accumulated knowledge to the newcomers and existing scholars.

5. Results

5.1. Landmark documents on AI in E-commerce

As shown in Fig. 4, to construct a directed acyclic citation network, this paper first deleted the duplicate records and 74 links representing the self-citation situation only considering the first author, obtaining a citation network consisting of 2252 vertices and 1789 edges. The average degree is 1.589, implying that each article within the network has built citation relationships with about two other articles. Then, this article extracted the largest subnetwork and converted it to a weighted network assigned by SPC value. At last, two main knowledge transmission paths were determined by applying different search techniques. As delineated in Fig. 6 and Fig. 7, vertices represent documents tagged with the first author's surname and publication year. The arcs represent citation relationships; arrows point from cited to citing articles, and the width of links indicates their importance.

5.1.1. Global main path analysis

The global main path consists of routes with the highest cumulative weight in the largest subnet. The first document on this path is Vellido et al. (1999). It adopted the neural network model, the unsupervised Self-Organizing Map (SOM), to conduct cluster-based market segmentation, which is conductive for mining numerous online transaction data. Albeit the SOM can flexibly accommodate both Finder Segmentation and Normative Segmentation approaches, other techniques needed to be combined, as it cannot specifically dig out clustering

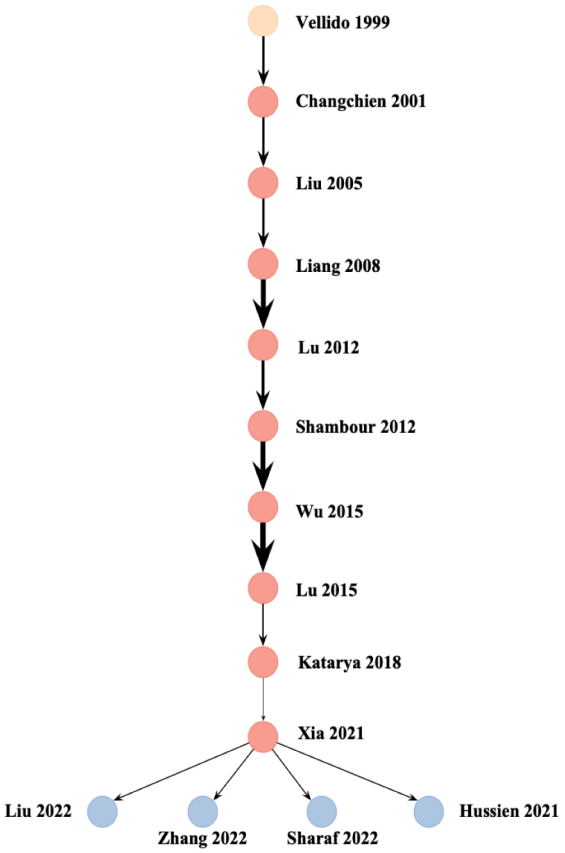


Fig. 6. The global main path.

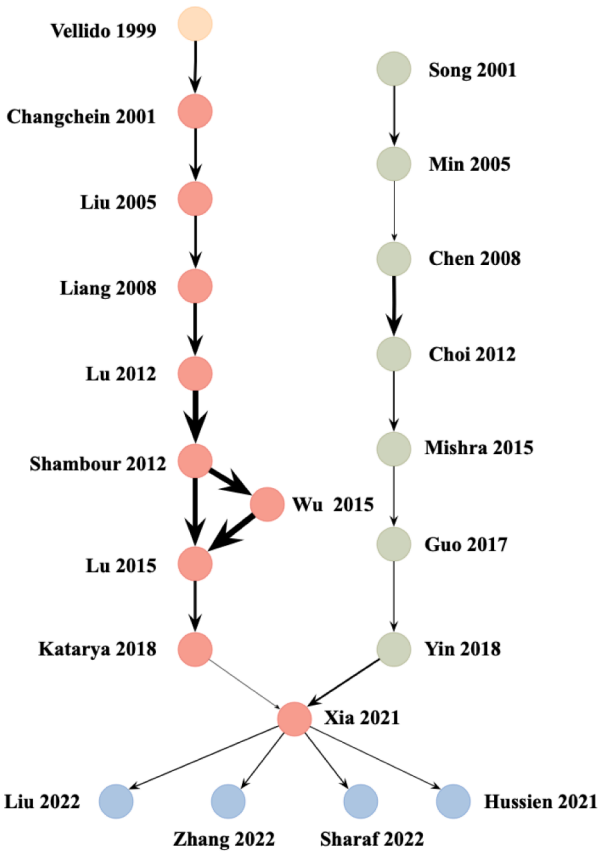


Fig. 7. The key-route global main path.

features. Therefore, Changchien and Lu (2001) integrated it with rough sets to extract association rules that can interpret the meaning of each cluster. Unlike the previous two articles focused on refining the applied AI algorithms to improve RSs' performance, Liu and Shih (2005) selected intelligent techniques from the consumer perspective and proposed two innovative hybrid approaches to consider customer lifetime value and purchase preferences.

Some essential cues will be missed when only investigating keywords in the content, and underlying semantic knowledge may not be captured. In the following years, researchers dedicated themselves to exploiting semantic information or considering organizational factors. Liang et al. (2008) adopted a semantic-expansion method that synthesizes semantic networks with content-based filtering for businesses to provide customization document recommendations. Lu et al. (2013) innovatively combined product taxonomy with fuzzy semantic similarity analysis to suggest personalized business partners for small and medium businesses (SMEs). Likewise, Shambour and Lu (2013) fused items' semantic information with a trust-relations network to alleviate the classical collaborative filtering problems, especially enhancing the coverage and accuracy of recommendations.

With the rapid propagation of information recording vehicles, researchers further turned to solve the structural complexity and vague preferences of items. Wu et al. (2015) first proposed a fuzzy tree-structured preference model with superior performance in matching data and identifying the corresponding components. During the same year, Lu et al. (2015) reviewed the RSs and their applications and summarized several application domains and related intelligent techniques based on content analysis. Katarya and Verma (2018) developed an effective movie-based RS that utilizes a *meta*-heuristic theory and fuzzy clustering algorithm to optimize the recommendation process.

Toward the end of the global path, there are five documents published after 2021. Contrary to previous studies considering outlier knowledge as noise, Xia et al. (2021) brought the existing mining algorithms and outliner detection technologies to RSs for managing comparatively fragmented and sparse information. Abdul Hussien et al. (2021) brought the statistical analysis to RSs to analyze customers' behavior for establishing a recommendation list that supplies recommendations close to the customer preference. To mine the consumer interaction between diverse digital platforms, Liu and Ding (2022) schemed a personalized recommendation module to detect emotional information and categorize it through the deep learning paradigm. Zhang et al. (2022) also employed deep learning to analyze the enterprises' indicators and determine possible procurement reengineering solutions. Sharaf et al. (2022) reviewed different aspects of RSs, including their definition, importance in our life, different types, and their advantages and problems, and further concentrated on financial services, their operation, and their different finance sectors on the other hand.

Through qualitative analysis of the above 14 nodes, this study has some important findings. First, most studies concentrated on RSs that allow the E-commerce market to thrive by engaging visitors into consumers and further fostering purchasers' loyalty. This research tendency is logical given that RSs have become integral to modern E-commerce platforms (Lee & Hosanagar, 2021; Stöckli & Khobzi, 2021). Secondly, *Decision Support Systems* and *Expert Systems with Applications* have published more papers, indicating that they have a high status in AI in E-commerce. Finally, the focus of the latter half of the main path shifts to promoting the application of different sorts of RSs in various scenarios, including the book-store field, the finance sector, and the healthcare field under the E-commerce background.

5.1.2. *Key-route global main path analysis*

This sub-section utilized the key-route search technique to zoom in on some routes with high-traversal values that also contribute to illustrating knowledge transmission trajectories on AI in E-commerce. The results are shown in Fig. 7, with seven more documents compared with Fig. 6, represented by the green nodes. This sub-section will focus on them.

Song et al. (2001) and Min and Han (2005) both applied association rule methods and time-related information to devise a method to automatically detect variations in consumers' behavior or interests. In the third document, Chen et al. (2008) considered the profitability factor for sellers and schemed two RSs aimed at increasing profits from cross-selling without compromising their accuracy. After that, sequential information taken into researchers' consideration, which also provides insights about the behavior of users along with content analysis, Choi et al. (2012) and Mishra et al. (2015) both schemed a novel hybrid system which, other than deriving implicit ratings or considering soft clusters, also integrates sequential pattern analysis with different algorithms to better predict users' behaviors and generate recommended results.

Due to the advent of wireless internet and mobile terminals, consumers' habits and needs have undergone major changes. Guo et al. (2017) developed a mobile-based RS involving the improved Apriori algorithm to develop mobile RS to provide a more convenient and simple shopping environment. Yin et al. (2018) viewed consumers as participants rather than receivers, and they considered incorporating initiative decisions into RSs designs through a feedback mechanism, i.e., association classification algorithms, to measure the RS effectiveness after consumer shopping has been completed.

Combining the above analysis, on the one hand, the commonality among these studies is that the performance of original algorithms is improved by incorporating AI-related techniques, thereby enhancing transparency, accuracy, and efficiency. Scholars have committed to exploring advanced AI to facilitate RSs in E-commerce platforms to analyze complex and ambiguous information, make sense of such data, and flexibly tap into those lessons to accomplish business goals. On the other hand, in the information explosion era, researchers realize

utilizing numerous dimensions of information while addressing information overload. For example, developing voice assistants and smart wearables can extract more data about people, which can be utilized in the RSs' design.

Compared to these resulting two paths, most nodes overlap, and this similarity validates the importance of these common documents in dissemination trajectories. The global main path reveals the research on AI in E-commerce from a macro-level that is the result of scientific studies aggregation. The key-route global main path reveals more details on AI in E-commerce, such as considering product profitability for organizations or developing the mobile RS. This combination is conductive to investigating and elucidating the full picture of AI convergence-divergence phenomena in E-commerce.

5.2. Thematic trends on AI in E-commerce

Citation network and co-word analysis (Garfield, 1994) are usually used to longitudinally monitor the progress of an academic domain over successive periods; this is conductive to broadening the train of thought, deciphering and tracking scientific knowledge evolution in turn (Donthu et al., 2021). This section aims to examine essential intellectual units and their interconnections on AI in E-commerce from another angle, thus comprehensively enriching the research results and presenting the intellectual infrastructure.

As illustrated in Fig. 4, based on the statistical analysis of the research field's growth, the paper divided 24 years into three consecutive time intervals, namely 1998–2016, 2017–2019, and 2020–2022. To guarantee the clarity of this study's results, during data preprocessing, some terms related to the topic research that may exist in every article were deleted, such as "electronic economic", "e-business" and "artificial intelligence", etc. Meanwhile, words with singular and plural forms or with similar meanings were merged into a word group; for example, "three-dimensional model" and "3D construction" were combined into the "3D". After careful cleaning and inspecting, the results were

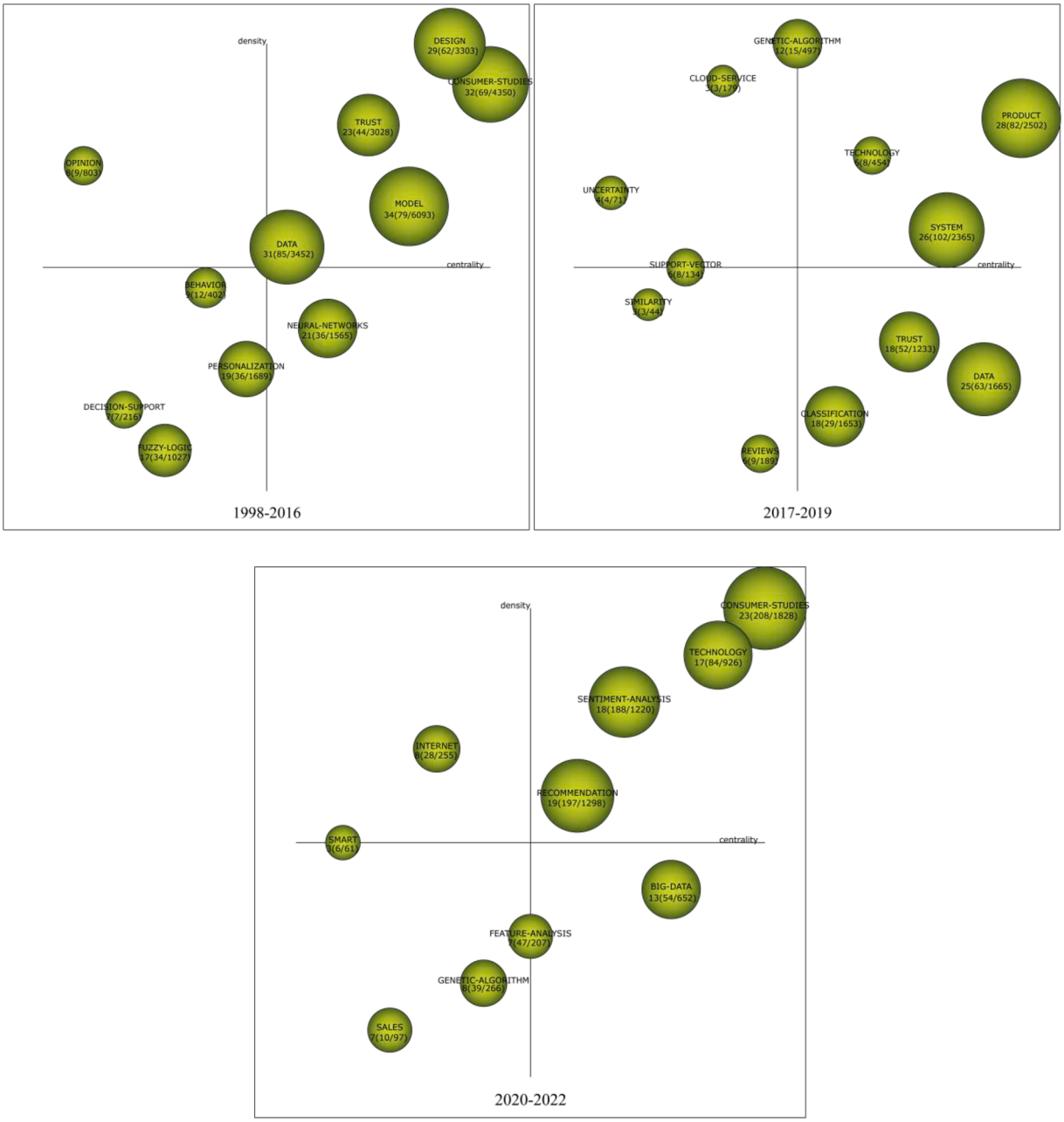


Fig. 8. The strategic diagram of three periods.

visualized in the strategic diagrams and conceptual evolution map, as illustrated in Fig. 8 and Fig. 9.

5.2.1. Periods' result—the strategic diagrams

This sub-section applied the strategic diagrams to investigate the most highlighted scientific foci (mainly the themes in the first and fourth quadrants) in each interval of the AI in the E-commerce domain (Cobo et al., 2015). In Fig. 8, the sphere is labeled with the core keyword in each theme, and the number of publications and citations are also supplemented in parentheses.

In the first period (1998–2016), the thematical motor cluster DESIGN and MODEL both obtained higher h-index values, the volume of the publication, and citation counts, which indicates that researchers are committed to providing a vehicle for dynamic modeling and fundamental designing. The motor themes also entail CONSUMER-STUDIES, TRUST, and DATA. Among them, CONSUMER-STUDIES is a pivotal applicational direction of AI in E-commerce, as it is bound up with several scientific topics, such as consumer relationship management, consumer behavior research, and consumer preference. TRUST embraces fewer documents but higher citations than other motor themes and mainly involves the establishment of agents' trustworthiness, which is derived from the users' perception of the reliability and the accuracy of the predictions. The thematical cluster DATA contains the maximum publications, including issues like data mining and web-text analysis, indicating most scholars have devoted themselves to meeting the challenges of information explosion and implementing several techniques to effectively prune large information spaces. Due to the characteristics of the algorithm, the density of NEURAL-NETWORKS is not very high, and some developments and improvements are still required.

During the second time interval (2017–2019), the motor theme PRODUCT receives the maximum citation counts and the best h-index value within this interval. It represents the studies undertaken in several facets of AI in E-commerce focused on the product task: product quality, online product reviews and networks, word-of-mouth convergence, or personalized product recommendation. GENETIC-ALGORITHM, TECHNOLOGY, and SYSTEM are motor themes mainly focused on advancing the usage of different techniques and optimizing existing systems. For example, Ahani et al. (2017) combined structural equation modeling and neural network analysis to investigate the complicated relations involved in the social relationship network established by SMEs. Remarkably, TRUST and DATA have evolved from the first to the fourth quadrant, suggesting that they still interact extensively with the rest, but

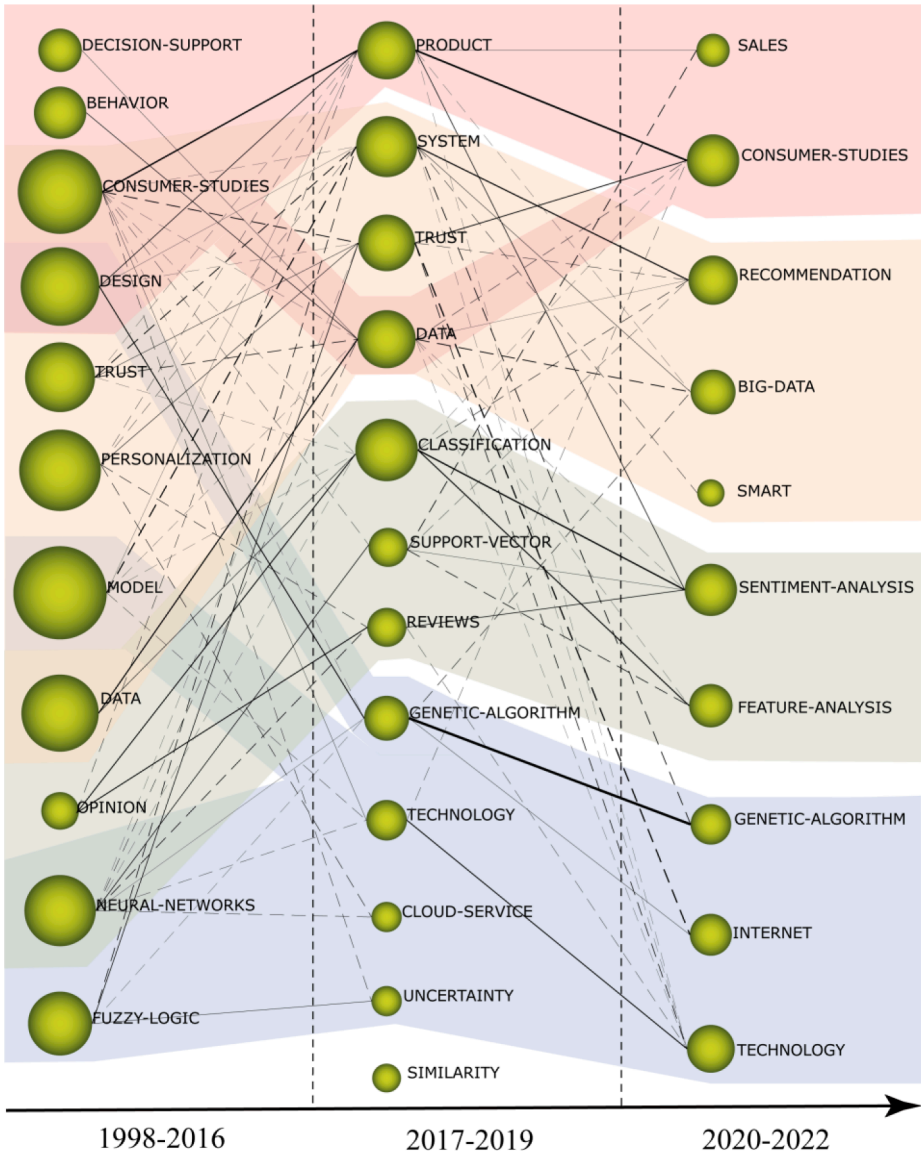


Fig. 9. The theme evolution map.

their internal cohesion decreases compared to the initial interval. As another basic and transversal theme, CLASSIFICATION also has great potential for further advancement in its own right.

Compared with the prior intervals, the clusters CONSTUMER-STUDIES and TECHNOLOGY consolidate as major themes, reach a relatively mature stage of their development, and closely interact with other themes, suggesting that associated issues have attracted the curiosity and attention of researchers and practitioners worldwide during the past several decades. Moreover, the remaining motor themes SENTIMENT-ANALYSIS and RECOMMENDATION, both obtain higher h-index values, along with a greater number of publications and citations. They also represent the two primary thematical arenas, that is, *Sentiment analysis* and *Trust and personalized recommendation*. Thanks to continuous advancements in cutting-edge data and telecommunications technologies, data volume waiting to be processed and interpreted presented unprecedented geometric growth. The thematical cluster BIG-DATA owns higher centrality, which aptly demonstrates that big data as a trigger has driven the rapid evolution of AI in E-commerce in the last decade. Specifically, big data analytics support organizations in tracking consumers to figure out appropriate ways that transform one-time users into repeat and loyal purchasers (Taylor-Sakyi, 2016). The basic and transversal theme FEATURE-ANALYSIS focuses on issues like feature extraction, feature fusion techniques, feature engineering, and so on.

5.2.2. Longitudinal result—the conceptual evolution map

Fig. 9 further reveals the identified thematic areas of AI in E-commerce, with a more detailed presentation in Table 2. Based on the "thematic nexus" and some semantic information, clusters belonging to the same thematic area are divided by different background colors. Finally, four thematic areas in the field of AI in e-commerce are identified: (1) *Optimization and decision support*; (2) *Trust and personalized recommendation*; (3) *Sentiment analysis*; (4) *AI theories with allied technologies*.

Optimization and decision support contains five clusters in the initial period: DECISION-SUPPORT, BEHAVIOR, CONSUMER-STUDIES, DESIGN, and DATA. During the second interval, there are two clusters within this region. DATA reappears, and most themes in the previous stage evolve into PRODUCT, specifically. *Optimization and decision support* ends in CONSUMER-STUDIES and SALES. *Optimization and decision* is a thematical arena focusing on various facets of product/service management, customer segmentation, promotions, the accuracy optimization of recommendation and prediction, etc. Considering the situations where the firms lack initial customer data (cold start problem), AI-related techniques could assist E-commerce organizations in increasing online revenue by refining dynamic pricing programs that calculate the most appropriate prices in an automatic pattern for different types of users.

In terms of *Trust and personalized recommendation*, most of the clusters in the conceptual evolution map are relevant to this region. It concentrates on CONSUMER-STUDIES, DESIGN, TRUST, PERSONALIZATION, MODEL, and DATA in the first interval, then morphs into SYSTEM, TRUST, and DATA. According to the bibliometric metrics, all of the above clusters perform well. During the last phase, it moves towards several motor clusters, namely RECOMMENDATION and BIG-DATA. This reflects that bringing intelligent techniques to trust-based RSs will facilitate E-commerce organizations to enhance customer satisfaction, making it an ideal solution to offset information overload and cultivate core competence. Additionally, improving RSs performance provides a research background for those recommendation agents, which consider the interests and habits of users implicitly or explicitly.

As for *Sentiment analysis*, this thematic region originates from DATA, OPINION, and NEURAL-NETWORKS, which are mainly located in the right quadrants and closely interact with the outside world. As this thematic area moves forward, it evolves into DATA, CLASSIFICATION, SUPPORT-VECTOR, and REVIEWS in the second phase. Lastly, it incorporates into SENTIMENT-ANALYSIS and FEATURE-ANALYSIS, which enable online platforms to make users' profiles and deliver personalized services by extracting features or analyzing semantic information from purchasers' reviews (Qiu et al., 2018). Consequently, adopting AI-powered sentiment analytics like machine learning or natural language processing would facilitate companies to better understand customer requirements and constantly adapt their marketing strategies based on perceived consumer sentiments.

The thematic region *AI theories with allied technologies* contains four thematical clusters in the initial interval: DESIGN, MODEL, NEURAL-NETWORKS, and FUZZY-LOGIC. During the second phase, there are four thematic clusters with higher internal cohesion, namely GENETIC-ALGORITHM, TECHNOLOGY, CLOUD-SERVICE, and UNCERTAINTY, which are mainly located on the upper quadrants in the strategic diagrams. Lastly, GENETIC-ALGORITHM and TECHNOLOGY reappear in this region, and INTERNET occurs as a new theme, including topics like unified theory, continuance intention, and perceived risk. Based on the investigation of the connected clusters over three stages, thanks to AI possessing the powerful computational ability to carry out cognitive functions, researchers are dedicated to applying different forms of technologies in E-commerce and improving their performance, as well as enriching concepts in the process.

Overall, the development of AI in E-commerce shows great cohesion, as most clusters originate from previous stages and can find their own thematic areas. The identified thematic areas also evolve in a compact and continuous manner from inception to the end.

Table 2
Main research thematical areas of AI in E-commerce.

Category	Corresponding theme
Optimization and decision support	decision-support, behavior, consumer-studies, design, data, product, consumer-studies, sales
Trust and personalized recommendation	consumer-studies, design, trust, personalization, model, data, system, trust, recommendation, big-data, smart
Sentiment analysis	data, opinion, neural-networks, data, classification, support-vector, reviews, sentiment-analysis, feature-analysis
AI theories with allied technologies	design, model, neural-networks, fuzzy-logic, genetic-algorithm, technology, cloud-service, uncertainty, internet

6. Discussion

Based on a comprehensive review of 2252 documents on AI in E-commerce, this article examined essential papers and transmission routes through main path analysis from the lens of global structure, as well as detected hidden themes and their interactions through science mapping analysis involving the strategic diagram and evolution map. To our knowledge, it is the first attempt to combine the main path with science mapping analysis to synthesize research on AI in E-commerce.

Regarding *RQ1*, critical documents located in chronological sequence on the main paths give the answer. The research on AI in E-commerce begins with employing an unsupervised neural network technique to characterize and analyze the expectations and preferences of online purchasers (Kohonen, 1982). Since then, there has been an explosion of studies on applying AI-related resources in E-commerce. Based on the qualitative analysis of articles, we found that most researchers in this community focus on addressing AI-related application issues, like refining systems' functional modules by incorporating the advantages of multiple algorithms, or evaluating their performance by adopting experiment-style research approaches. Therefore, studies particularly emphasize the enhanced-RSs, which utilize intelligent techniques in the rear end to understand users' behavior or provide decision support. Recent studies focus on the effective applicational ways of intelligent algorithms like principal component analysis,

support vector machine, K-means, etc., to analyze and model E-commerce phenomena. Through simulating practical applicational scenarios, researchers are dedicated to improving the agent algorithms that facilitate commerce systems' learning modules.

In terms of *RQ2*, this article adopted science mapping analysis using strategic diagram and evolution map and found that data, algorithms, and models are key AI basic resources contributing to the transformation and development of E-commerce. Four main AI-enabled outcomes in E-commerce were observed: *Optimization and decision support* related to evaluating online reputation and credit risk; *Trust and personalized recommendation* focused on consumer behavior and intelligent agents; *Sentiment analysis* related to interpreting and classifying emotions and attitudes; *AI theories with allied technologies* representing the stream of studies concentrated on knowledge sharing and automation. Moreover, the interconnected themes in one area hint at the resources that E-commerce firms might need to orchestrate when developing firm capabilities and gaining competitive advantages. For example, the themes DATA and NEURAL-NETWORKS belong to *Sentiment analysis*, which shows that orchestrating AI resources alongside other resources is beneficial for E-commerce sectors in conducting sentiment analysis. Specifically, AI consumes vast quantities of data to gain insights, make forecasts, and identify patterns (Sipior, 2020). This aligns with the expectations of previous studies that emphasize the importance of data reliability and availability in realizing the value of AI (Ranjan & Foropon, 2021). Models also play a pivotal role, as there is a growing demand for quickly processing and leveraging data for real-time decision-making and optimization in E-commerce. This indicates how models act as "the building blocks" that constitute AI. As shown in Fig. 10, through automating, augmenting, and transforming crucial business processes, AI contributes to gaining enterprise competitive advantage either in effectiveness (e.g., personalized recommendation) or efficiency (e.g., decision support), or both.

Regarding *RQ3*, in contrast to traditional approaches to accessing the intellectual capital related to AI in E-commerce, the analytical framework proposed in this paper relies on complex network analysis of large text datasets. It might be transferable to investigate the evolutionary process of knowledge infrastructure in other domains of interest, requiring relatively little pre-analysis information while yielding clear and verifiable evidence. In terms of application effect, the mainstream research orientations and tendencies of AI in E-commerce are consistent, regardless of whether it is viewed from the lens of knowledge units' transmission or evolution. The results of the two types of knowledge networks are complementary. The former focused on RSs and showed the foundational juncture papers. The latter utilized the strategic diagram and evolution map to highlight sentiment analysis, personalization, and fuzzy logic as the core thematical clusters of AI in E-commerce. For example, researchers could leverage the resources mentioned in the former to enhance the performance of their sentiment-based, personalized, and fuzzy logic-based RSs.

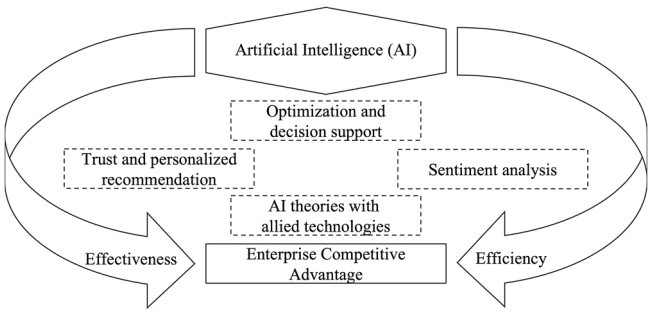


Fig. 10. A conceptual framework of orchestrating AI-related resources to gain competitive advantage in E-commerce enterprises.

6.1. Research prospects

In light of the outcomes from science mapping analysis and main path analysis, as well as main findings contributed by other scholars, some research directions can be identified: (1) Scholars have primarily utilized intelligent algorithms and systems in their studies, such as expert systems, deep learning, and voice assistant, to assist E-commerce activities around the value chain. What is the nature of these systems and algorithms? When a technique facilitates E-commerce organizations to forecast and manage knowledge, does that mean it is AI? It is imperative for scholars to give a clear explanation about what they are referring to and distinguish between AI and machine intelligence applied in their studies to avoid misunderstandings and confusion. (2) It is undenied that those researchers strongly focus on RSs, including investigating the influence factors or exploring the effective ways of redesigning conversational RSs. However, most researchers employed extant datasets or self-established repositories to test their proposed systems without connecting to real-world applicational scenarios (Adam et al., 2021), which cannot guarantee the test output and performance of the improved AI-related techniques to remain reliable in practice. (3) There has been a growing demand for research on how AI can support decision-making (Brynjolfsson et al., 2021). Specifically, researchers have become interested in investigating how AI-related techniques might influence traditional managerial behaviors and mindsets and further affect the rationality of E-commerce agents or consumers. Also, the academic community is actively exploring the ethical decisions (Di Vaio et al., 2023a; Vimalkumar et al., 2021) that E-commerce practitioners may encounter when implementing intelligent algorithms and systems. However, our research shows that decision support has not yet received widespread attention; the upcoming studies on AI in E-commerce are expected to advance this topic.

6.2. Theoretical and practical implications

This article contributes to developing this scientific research and technical practice through an innovative synthesis of the documents on AI in E-commerce. Despite recent studies treating AI and E-commerce as important academic topics in the information systems discipline (Jeyaraj & Zadeh, 2020), few reviews have investigated its evolutionary process involving flow trajectories and evolution structure. Building the research orchestration perspective, this article attempts to address this void by analyzing co-word relationships and referential behavior.

First, the resource orchestration perspective is crucial for comprehending the intricate interaction between AI-related resources and other capabilities within E-commerce. It allows for a more holistic understanding of how AI capabilities develop and interact with various resources over time, ultimately influencing value creation in the business context. Without this perspective, it would be challenging to grasp the full extent of AI's impact and its potential in E-commerce for long-term growth and innovation. For academic researchers who want to explore given resources in a certain business context, it provides an appropriate analytical perspective, to encourage their analysis to go beyond the investigated technologies and explore how to collaborate with other existing resources, systems, and processes to achieve success within businesses.

Second, this paper dug out the evolutionary process of knowledge infrastructure in this domain, constituted by landmark documents and core themes. This investigation could assist researchers in predicting emerging trends and assessing the significance and innovation of their studies' topics relative to other aspects within this field, thereby enhancing academic efficiency on practical problems. For educators who formulate instructional orientations for programs on E-commerce or AI in some universities, the demonstrated foci precisely what future education should revolve around, such as RSs and BDA. It is also relevant for researchers in the scientometrics domain; the analytical framework of this article can be applied to investigate their targeted fields, such as

cross-border E-commerce and smart logistics.

Third, the present paper's findings provide practitioners valuable guidance and information to AI practice in E-commerce to make better decisions in business operations. Given that introducing AI-related technologies is inseparable from resource orchestration and organizational change, driving intelligent transformation requires not only financial investments and human resources but also sufficient intangible assets, such as time, effort, and appropriate organizational culture. Whereas the application of AI in E-commerce requires unique access rights, ownership of consumer information, and intelligent algorithms that adapt to the organizations' situation (De Smedt et al., 2021; Shi et al., 2020), which is almost impossible for competitors to imitate and might facilitate the enterprises stand out in the in a fiercely homogeneous market. For policymakers dedicated to addressing digital challenges with minimal resources, they should focus on these AI technology drivers and further bridge the missing links of technology-oriented policies.

Fourth, this research article provides a starting point for future academic studies. Specifically, it reveals hidden themes, recent studies' foci, frontiers, and several knowledge landmarks in dissemination trajectories from a multidisciplinary perspective. Thus, it is easy for scholars and practitioners concerned with integrating AI into E-commerce to locate the scientific documents that most closely match their needs, and this could spare them time in looking for documents that might not always be reliable and relevant.

7. Conclusion

Due to the increasing difficulties encountered in offline transactions, especially with the advent of COVID-19, AI has evolved as an important means of nurturing the sustainability of E-commerce companies. Confronted with the vast amount of research documents, undertaking qualitative and quantitative methods to analyze the research on AI in E-commerce in depth is necessary. Based on 2252 documents from 1998 to 2022 from the WoS, this article adopted main path analysis to illustrate the key knowledge transmission routes. This study also investigated how important intellectual units evolve over time by dividing 24 years into three different intervals.

Synthesizing three classical bibliometric indicators to statistically analyze the number of publications, it is obvious that China, the USA, and India are leaders in this research area. According to the nodal literature on two knowledge transmission paths, RSs are highlighted as the most investigated. Finally, science mapping analysis using the strategic diagram and evolution mapping investigated the key academic themes and their performance characteristics and inter-relationships. Conceptual snapshots of different intervals show that early research focused on models, design, consumer studies, etc., while later focused on emerging themes such as fuzzy logic and personalization. Four thematic areas were also identified, involving *Optimization and decision support*, *Trust and personalized recommendation*, *Sentiment analysis* and *AI theories with allied technologies*.

Although this article attempted to present an all-embracing review regarding the research on AI in E-commerce, we cannot deem it is exhaustive, and there are still some limitations. Firstly, this paper retrieved only the SCIE and SSCI databases in the WoS, and we still can't include various applicational forms of AI when setting the search scope. Some documents may have been published after the time this article started reviewing; thereby, the results may not accurately reflect the full range of theoretical and applicational developments. Secondly, main path analysis simplifies the complicated citation network to a few straightforward key routes; our findings might differ slightly from some researchers' perceptions as a result of inherent citation bias, and the properties of the algorithms make the nodes on the main path not fully disclose every highly cited literature within the domain. Lastly, when performing science mapping analysis, data need to be preprocessed, including merging and deleting certain terms, so it might have a subtle impact on the results. Nonetheless, the findings from our studies are consistent with those of similar papers we cited. Therefore, we consider that our contributions to AI in E-commerce are still relevant and reliable.

CRediT authorship contribution statement

Xiaorong He: Conceptualization, Software, Writing – review & editing. **Yan Liu:** Conceptualization, Methodology, Software, Visualization, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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