IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 17 November 2024, accepted 9 December 2024, date of publication 11 December 2024,
date of current version 19 December 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3515290

RESEARCH ARTICLE

Innovation Ecosystems in Retail: Uncovering Technological Trends and Collaboration Networks Through Patent Mining

NAVID MOHAMMADI[1], MEHRDAD MAGHSOUDI[2], AND MAHDI SOGHI[3]
[1]Faculty of Commerce and Trade, College of Management, University of Tehran, Tehran 1417935840, Iran
[2]Management and Accounting Faculty, Shahid Beheshti University, Tehran 1983963113, Iran
[3]Master of International Business, Faculty of Commerce and Trade, University of Tehran, Tehran 1417935840, Iran

Corresponding author: Navid Mohammadi (Navid.m@ut.ac.ir)

ABSTRACT Retail technology adoption is essential for improving operational efficiency, enhancing customer engagement, and supporting sustainable growth in a highly competitive environment. Despite the growing importance of digital transformation in retail, significant research gaps remain in understanding collaborative innovation networks within this sector. This study addresses these gaps by utilizing Social Network Analysis (SNA) to examine patent registrations in retail technology, analyzing a dataset of 36,411 patents from 1995 to 2024. The methodology includes network construction, community detection, and keyword analysis, mapping out 8,225 entities and 14,805 collaborations. Results reveal IBM, Target Brands, and Procter & Gamble as pivotal entities with high network centrality, highlighting their influence across key technological domains like AI, digital commerce, and retail security. The research categorizes technologies into 15 domains—such as Core Retail Operations, Digital Commerce, and Retail Communication—exposing seven major clusters where innovation efforts are concentrated. These findings offer practical insights for corporations, SMEs, startups, and policymakers aiming to navigate technological change and optimize strategic investments in retail. By detailing the relationships between leading entities and emerging technology clusters, this study provides a comprehensive view of the retail innovation landscape, aiding stakeholders in decision-making around technology adoption, collaborative opportunities, and competitive positioning in an increasingly digital retail ecosystem.

INDEX TERMS Retail technology, patent analysis, social network analysis (SNA), digital commerce, retail industry collaboration, data-driven decision-making.

I. INTRODUCTION

Retailing is a vital driver of economic growth, job creation, and consumer spending in the worldwide market [1], [2]. The retail industry plays an essential part in international trade, affecting not just individual nations but also the global economy [3]. The retail industry is complicated and has a significant impact on multiple facets of society, including shaping identities and values and driving economic growth [4], [5]. It facilitates the transfer of products and services between producers and consumers and promotes the implementation of sustainable distribution and consumption methods [6]. Moreover, retailing offers an opportunity for economic expansion in developing nations and acts as an essential catalyst for developed nations [7]. The sector's significance extends above basic transactions, as it has an impact on cultural norms, political landscapes, and societal structures [4]. The retail sector is intricately associated with concepts such as supply chain management, the digital economy, geopolitical and economic factors, and e-commerce [8], [9], [10].

According to Woods et al. [11], a wide range of technologies, including artificial intelligence (AI), big data analytics, the Internet of Things (IoT), blockchain, automation,

The associate editor coordinating the review of this manuscript and approving it for publication was Yin Zhang.

robotics, and virtual reality, are increasingly being used in retail operations. The widespread implementation of cutting-edge technologies has completely transformed traditional retail procedures, resulting in significantly improved efficiency, personalization, and customer satisfaction. These technologies have influenced conventional retail strategies and technologies regarding operations, customer services, and business outcomes [12], [13]. The use of advanced technologies like AI has made it possible for retailers to analyze data, provide recommendations, control inventory, and perform several tasks, thereby enhancing their productivity and satisfying consumers [14]. Further, AR, cloud computing, and big data analytics have created the possibility of Retail 4.0, which enables retailers to offer new services and value-added solutions to consumers [15]. Therefore, according to Chand [16], technological advancement has become inevitable for retailers who want to survive in the market, and this has forced the retail sector to go for the digital transition. By using technology, merchants can optimize operational efficiency, promote consumer interaction, and stimulate sustainable growth in a progressively competitive market [15].

As for the field of retail, the application of technology is now mandatory for organizations and companies that aim for growth and sustainability. It is therefore important for businesses to be aware of the technological trends and the flow of technology in the retail industry [17], [18]. Among the most widely used approaches, it is important to highlight patent mining, which is aimed at analyzing patents to determine emerging technologies, innovative solutions, and directions for their further development [19], [20]. Thus, through the analysis of patents, retailers can identify the latest technologies, competitors, and trends, which will help them make the right decision on the use of technology. Retailers must be aware of technological innovations and developments to be able to compete effectively, increase productivity, deliver superior customer experiences, and improve their business in the constantly evolving retail environment [21], [22]. By leveraging patent mining as a strategic tool, retailers can proactively identify opportunities for technological integration, innovation, and differentiation, ultimately positioning themselves for success in the digital age [23], [24].

Nevertheless, despite its impressive growth and impact, there remains a clear gap in our comprehension of the retail industry when examined using data-driven research [25], [26]. The study by Trappey et al. [27] introduces an ontology-based method for evaluating patent portfolios within smart retailing, producing patent maps that delineate relationships among patents, innovations, and business processes, but it is narrowly focused on specific companies, limiting the generalizability of its findings across the broader smart retailing industry. Mondol [28] investigates how blockchain technology affects supply chain performance in the UAE's retail sector, finding significant enhancements in inventory systems and overall supply chain outcomes. However, The study relies heavily on primary data from a single retail entity, LuLu Hypermarket, which may not provide a comprehensive view of the sector's wide variability. Reference [29] focus on the economic and patent landscape impact of smart retailing, showing how emerging technologies drive the shift from physical to virtual store experiences.

Previous research in the retail sector has largely centered on the application of specific technologies such as blockchain, often failing to fully capture the complex, multidimensional impacts these technologies have on the industry, and providing limited insights into broader strategic implications or integration challenges across diverse retail environments [27], [28]. Similarly, other researchers propose technology roadmaps that, while informative, largely overlook critical factors of retail markets [19], [30]. The few attempts to employ patent mining for broader technological trend analysis concentrate predominantly on RFID applications, significantly neglecting other rapidly evolving technologies that could revolutionize the retail sector [31], [32]. These studies collectively demonstrate a piecemeal approach to understanding retail technology, often constrained by narrow scopes and limited by a lack of comprehensive integration strategies, thereby leaving significant gaps for more holistic and dynamically adaptable research contributions [33], [34]. Also, there is a noticeable gap in the literature on the main entities and companies driving the technological aspect of the retail industry, their focuses, and how they are interconnected [35], [36]. This literature gap is quite alarming, especially due to the current high rate of technological innovation and the growing significance of innovation as a source of competitive advantage in the retail industry [37]. Although earlier research has emphasized the significance of technology as a crucial factor for successful retailers, there is a need for a comprehensive analysis of different technological developments, advances, and their consequences for the retail industry [38], [39].

Despite the retail sector's rapid technological advancement, current research reveals substantial gaps in our understanding of its broader implications. Existing studies often focus on specific technologies, such as blockchain or RFID, yet do not fully capture the complex and interconnected impacts that these innovations have across retail environments. Many analyses remain limited to isolated case studies or single-company data, which hinders the ability to generalize findings to the wider industry. For instance, studies like Trappey et al. focus on narrow ontology-based patent evaluations, and Mondol's work on blockchain in the UAE's supply chain, while insightful, lacks applicability across diverse retail ecosystems. Other studies propose technology roadmaps, but these often overlook the multidimensional strategic integration needed to support technology adoption in various retail segments. Additionally, while some research investigates technological trends via patent mining, it frequently emphasizes specific innovations, such as RFID, overlooking other disruptive technologies that could transform the industry. Further, there is a limited exploration

of key players and their roles in driving and connecting technological advancements, underscoring a critical gap in mapping the sector's innovation ecosystem. This fragmented approach has yet to address the need for comprehensive, integrative strategies to support stakeholders—from major corporations to SMEs—in navigating rapid technological evolution. Consequently, a more holistic, data-driven exploration of emerging retail technologies is needed to illuminate the broader strategic opportunities and integration challenges facing the industry today.

In recent years, patent analysis has become an essential tool for assessing technological trends, understanding competitive landscapes, and promoting innovation. Effective patent analysis allows companies, researchers, and policymakers to identify technology gaps, monitor advancements, and gain insights into competitor strategies. Among various approaches, machine learning-based patent analysis has gained particular attention due to its ability to manage large datasets and uncover valuable insights from complex patent information [40]. This method uses advanced algorithms to process patent metadata, textual content, and citation networks, making it possible to identify hidden patterns, relationships, and trends within extensive patent databases. Machine learning-based methods are not only efficient in processing time but also highly adaptable, allowing customization for specific technological domains or industries. Furthermore, these approaches provide a robust framework for predicting innovation trajectories, evaluating the potential impact of emerging technologies, and guiding strategic decision-making in research and development [41]. Consequently, machine learning-based patent analysis has emerged as a cutting-edge approach that empowers stakeholders to harness the full potential of patent data for competitive and strategic advantage [42], [43].

This research aims to address this gap in the literature by using Technology Network Analysis (TNA) to classify the various kinds of retail technologies and identify the most suitable ones. The goal is to provide findings that can be helpful for large corporations, SMEs, startups, and researchers regarding planning, development, financing, and policies in cooperation. Therefore, the following questions are aimed to be answered in this paper:

- Q1. What is the structure and composition of the cooperation network involved in the registration of retail industry patents?
- Q2. Who are the prominent figures and organizations in the retail industry patent network, and what roles do they fulfill?
- Q3. What are the primary technological domains represented by main participants in retail industry patents, and how do they contribute to the modernization and efficiency of the sector?
- Q4. What trends are evident in the investment and concentration strategies of main actors across various technologies within the retail community?

The remaining sections of the paper begin with the Literature review, followed by the Methodology section, which dives deep into the research method used for this analysis. Next, the results section presents the outcomes, including the Formation of the Retail Industry Patent Registration Network and the Keywords Network. Next, the Discussion, followed by the Conclusion section, synthesizes the findings and emphasizes the role of technological innovation in shaping the retail industry's future.

II. LITERATURE REVIEW

A. RETAIL TECHNOLOGIES

Khashan et al. [44] argue that the Retail industry as we know it is undergoing a significant technological transformation. Moreover, these advances are adapting consumer interactions with retail and influencing brand loyalty [45]. As Bălăşescu [46] discussed, understanding the impact of technological advances in retail innovation is fundamental for shaping the future retail experience and improving business models Bruni and Piccarozzi [47] determined the three sections that technology in retail is going to be utilized, including analyzing customer behavior, enhancing customer relationship management, and optimizing retail management. In addition, Li [48] demonstrates that supply chain relationships are paramount for moderating and facilitating digital transformation and innovation performance in retail companies, providing insights that support the necessity of reconfiguring relationships within the supply chain to foster innovation in retail. Luamba et al. [49] further establish that innovative strategies are critical for small retailers to remain sustainable, with technological innovation allowing real-time monitoring of commercial activity and inventory evaluations Nurjanah [50] outlines a new concept that can be described as the fusion of digital and physical environments of retail establishments, leading to a seamless and immersive shopping experience for customers. This new concept, ''New Retail'', relies on a consumer-centric approach in which big data and AI technologies are integrated to optimize the processes of production, circulation, and sales. Moreover, Evanschitzky et al. [51] argue that digital disruption is a major force that impacts the retail sector, and technologies such as service robots will continue to evolve and change the retail landscape. Additionally, Cakir et al. [52] has claimed that Omnichannel retailing is a disruptive trend that has impacted the retail sector. omnichannel retailing is a customer experience strategy that offers a seamlessly integrated and consistent experience across all feasible customer interfaces and touchpoints, transcending traditional retail limiting experiences through digital technology.

Butt et al. [53] illuminate that new technologies like AR and employee services are utilized to engage customers, strengthening equity and fostering loyalty in the retail sector. Researchers have claimed that the integration of AR technology at retail is reshaping conventional retail methods and enhancing supply chain processes through

TABLE 1. Main technologies of the retail industry.

Technology	*Applications*	*Impact Areas*	*References*
Augmented Reality (AR)	• Enhancing shopping experience • driving customer adoption • engaging customers • strengthening equity • fostering loyalty • Experiential Marketing • Reducing Decision-Making Uncertainty • Advertising Tool	• Reshaping retail methods • enhancing supply chain processes • influencing brand loyalty • Consumer Behavior and Purchase Intentions • Technology Acceptance and User Experience	[12, 44, 45, 59-63]
Artificial Intelligence (AI)	• Enhancing supply chain processes • Personalized Shopping Experiences • Dynamic Pricing • Inventory Management • Predictive Analytics	• Influencing consumer interactions • improving brand loyalty • Customer Segmentation • Marketing Strategies	[12, 45, 50, 64-68]
Internet of Things (IoT)	• Energy Optimization • Inventory Control • Customer Interaction • Data Capture and Analysis • Sustainable Practices	• Supply Chain Optimization • Operational Efficiency • Data-Driven Decision Making • Risk Mitigation	[56, 57, 69-73]
Service Robots	• Innovating Retail Services • Improving Operational Efficiency • Enabling Contactless Services • Adapting to Changing Consumer Preferences	• Effecting digital disruption • Customer Satisfaction and Loyalty • Employee Well-being • Emotional Experiences	[51, 74-78]
Real-time Monitoring Technology	• Monitoring commercial activity • inventory evaluations • Demand Forecasting • Loss Prevention • Performance Monitoring	• Sustainability of small retailers • Pricing Strategies • Predictive Maintenance	[49, 79-81]
Virtual Reality (VR)	• Creating immersive shopping experiences • Real-Time Product Displays • Virtual Try-On Capabilities • Virtual Fitting Rooms	• Enhancing customer experience • increasing engagement • Increased Purchase Satisfaction	[55, 62, 82, 83]
Blockchain	• Ensuring transparency and security in supply chain management • Improved Traceability • Mitigation of Fraudulent Activities • Streamlined Logistics • Customer Data Protection	• Reducing fraud • improving traceability and trust • Cybersecurity Enhancement • Supply Chain Sustainability	[58, 84-89]
Chatbots	• 24/7 Customer Support • Reducing Wait Times • Personalization and Engagement • Efficiency Enhancement • Improved Service Capabilities	• Enhancing customer service • increasing efficiency • Improved Customer Engagement • Data Collection and Analysis	[54, 90-95]
RFID (Radio Frequency Identification)	• Real-Time Inventory Tracking • Logistics Efficiency • Anti-Counterfeiting Measures	• Enhancing inventory management • Optimized Inventory Visibility • Omnichannel Strategies • Cost-Effectiveness and Efficiency	[32, 96-99]
Cloud Computing	• Managing data storage • supporting e-commerce platforms • enabling scalability	• Reducing IT costs • increasing flexibility	[100-103]
Geolocation Technology	• Offering location-based promotions • tracking customer movement in stores • Enhanced Customer Targeting • Geotargeted Advertising • Competitor Analysis	• Enhancing targeted marketing • improving store layout optimization • Brand Image and Customer Value	[104-107]

artificial intelligence (AI) and customer service capabilities through chatbots [12], [54]. Virtual reality (VR) in the retail industry enables the realistic representation of products, virtual store experiences, and improved user involvement, therefore revolutionizing consumer interactions and purchase habits [55]. Al-Nabet [56] and Roe et al. [57] have emphasized that the Internet of Things (IoT) is critical to transforming the retail industry worldwide. Blockchain technology in the retail industry facilitates enhanced supply chain traceability, product authentication, and secure transactions, potentially revolutionizing operational efficiency and consumer trust [58]. Table 1 provides a detailed representation of the main technologies used in the retail industry and their respective applications and impact areas.

B. PATENT MINING IN RETAIL

Patent mining is crucial for driving innovation and maintaining a competitive edge in today's market [107], [108].

As Sarica et al. [109] discussed, by systematically extracting and analyzing information from patent databases, companies can identify technological trends, track competitors, and uncover market gaps for new product development. Ponta et al. [110] highlighted that this process also aids in optimizing research investments, avoiding potential infringements, and informing strategic decisions on licensing and intellectual property management. Additionally, patent mining supports policymakers and legal experts in shaping effective patent strategies, ensuring compliance, and drafting robust patents [111]. Overall, it is an essential tool for sustaining innovation and safeguarding intellectual assets [112], [113]. Alessandri [114] argued the effectiveness of patent mining across numerous industries and domains, highlighted by researchers, emphasizes the relevancy of patent mining in grasping the complex innovation landscape within particular sectors and from varying locations.

As for the retail industry, Liu et al. [115] and Hwang et al. [116] highlighted the significance of patent mining in uncovering technological patterns and gaining insights into the wider scope of innovation. Through the utilization of techniques such as text mining and bibliometric analysis on extensive patent datasets, these researchers successfully extracted crucial insights regarding innovation trajectories and competitive landscapes. This technique has been extremely beneficial for retail organizations who want to remain ahead of technological developments and take advantage of future opportunities.

Similarly, the research conducted by Guderian et al. [117] has specifically examined the strategic application of patent mining as a means of managing risks and promoting innovation in times of crisis. Guderian et al. [117] demonstrated the usefulness of patent mining in helping organizations discover innovation trends and plan strategic responses to unexpected problems during the COVID-19 pandemic. This study emphasized the significance of patent mining during times of uncertainty.

In addition, Jun [118] and Huang et al. [119] investigated the incorporation of patent mining with other data sources, such as academic research databases, to improve technical roadmaps and expand competencies in the retail industry. By utilizing sophisticated methodologies such as boosting and ensemble learning on patent big data, they showcased the potential of these techniques to enhance our comprehension of technology integration, a crucial aspect in the rapidly evolving retail industry.

C. RELATED WORKS

Trappey et al. [27] introduce an ontology-based approach for evaluating patent portfolios, offering competitive insights through text mining and patent categorization within smart retailing. This method generates patent maps that reveal relationships between patents, innovation categories, commercial potential, and business processes. Their three-dimensional model assesses patents by scope, importance, and originality. The study finds Amazon's patents highly innovative but specific, while Alibaba's patents cover broader sectors with average influence. This approach provides strategic information for informed R&D and innovation management decisions, highlighting the importance of organized patent portfolios in smart retailing. Ozcan et al. [19] apply integrated road mapping to forecast upcoming technologies in retail, addressing a gap in the literature on emerging technology adoption. The study uses a mixed approach, analyzing patent data and expert reviews, and categorizing eight technology groups into a comprehensive roadmap with a focus on unmanned retail operations. The findings indicate significant changes in front-end and back-end retail activities, impacting strategic innovation management. This twelve-step process provides valuable insights into technology foresight, contributing to the literature on technology forecasting and its application in retail frameworks. Trappey et al. [29] investigate the patent landscape and economic impact of smart retailing on companies like Alibaba and Amazon. Using Pierce's Derwent Innovation search, the study highlights a rise in patents related to e-transactions, customer experience, and information integration. It shows how technologies like AI, AR, and NFC are driving a shift from physical to virtual store experiences, while also addressing the challenges of data privacy and cybersecurity, and the economic potential for the workforce and future investments in smart retailing. Pantano et al. [120] examined patent trends in the retail sector from 1990 to 2015, demonstrating exponential growth with a two-year doubling rate, highlighting the critical role of technological advancement in enhancing competitiveness. While the initial TPC model underestimated patent activity from 2005 to 2015, a revised model better captures this upward trend. The study observes a deceleration in patent growth post-2005, with further slowing anticipated after 2018, indicating a potential phase of technological diffusion. This research underscores the strategic significance of patent analysis for innovation tracking, competitive advantage, and improving customer experiences in the retail industry.

The study by Mondol [28] investigates the effects of blockchain technology on supply chain performance in the UAE's retail sector, focusing on the LuLu Hypermarket. Using a quantitative approach, the study collected primary data through questionnaires and secondary data from published sources. Path analysis, ANOVA, regression, and correlation analyses confirmed that blockchain significantly enhances smart inventory systems and supply chain outcomes. These findings emphasize the importance of blockchain in improving operational performance, reducing costs, and boosting competitiveness in the retail sector. The study advocates for the adoption of blockchain and smart inventory systems to optimize supply chain processes and maintain market advantage. Lu et al. [30] investigate AI integration in retail through a technology roadmap approach. They classify AI development into four phases: data gathering, personalized services, IoT-powered data integration, and advanced AI applications like image and speech recognition.

TABLE 2. Summary of related works.

Year	*Research Topic*	*Research Method*	*Main Research Result*
2023	Impacts of Generative AI in Retail	Analysis of various sources on AI applications in retail	AI enhances inventory management and customer engagement, emphasizing the need for capital investment to sustain market competitiveness.
2022	Forecasting emerging technologies in retail	Mixed approach: patent data analysis, expert reviews, twelve-step process	Shift towards unmanned retail operations; significant changes in retail activities
2022	Technology Roadmap of AI in Retail	Technology roadmap methodology analyzing real-life AI applications in retail	Classified AI development into four phases, providing a framework for structured AI implementation to improve retail operations and consumer experiences.
2021	Blockchain Technology in Supply Chain Performance	Quantitative research with primary and secondary data collection	Confirmed positive effects of blockchain on smart inventory and supply chain outcomes, highlighting its role in improving operational performance and competitiveness.
2020	RFID Tracking System for Retail Analytics	Analysis of RFID signals using deep learning networks	The TagSee system tracks customer movements with over 90% accuracy, offering a privacy-focused alternative to traditional retail analytics.
2019	Evaluating patent portfolios using ontologies	Text mining, patent categorization, smart retailing ontology, valuation model	Amazon's patents are highly innovative but specific; Alibaba's patents cover more sectors with average influence
2019	RFID Technology and Robotics in Retail	Design and evaluation of a model for RFID robots	RFID robots achieve over 99% accuracy in stock counting, enhancing inventory management and reducing manpower costs.
2018	Patent analysis and economic impact of smart retailing	Pierce's Derwent Innovation search	Rise in patents for e-transactions, customer experience, and information integration; AI, AR, and NFC influencing behavior
2018	Historical trends and future predictions of retail patents	Analysis of patent growth, TPC model prediction	Exponential patent growth with a doubling rate of two years; potential slowdown in patent submissions post-2018

Analyzing 30 real-life cases, the study identifies 16 service and 10 technological AI applications, offering a structured framework for businesses to enhance consumer experiences and operational efficiency as they adopt AI. The study conducted by Kulkarni [65] examines GenAI's impact on retail, particularly in inventory management, personalized shopping, and customer engagement. The authors show how AI improves demand forecasting, shopping experiences, content selection, and emotion assessment. The study highlights AI's role in boosting efficiency and innovation, emphasizing that competitiveness in retail demands significant capital investment to sustain these technological advancements.

Ali et al. [31] introduced TagSee, a system that uses RFID devices and deep learning to track customer movements without contact or cameras. By analyzing RFID signals with commercially available tags and readers, TagSee achieved over 90% accuracy, offering a novel, privacy-focused alternative for enhancing retail analytics. Morenza-Cinos et al. [32] explore the use of RFID technology with robots to automate stock counting in retail, achieving over 99% accuracy with a new inventory navigation algorithm. The study shows that RFID robots improve accuracy, save time, reduce manpower costs, and enhance inventory management, contributing valuable insights for future supply chain research. Table 2 offers a concise overview of the topic, the method, and results from previous studies.

This paper delineates its uniqueness and academic contribution by employing SNA to intricately explore the patent registration network in the retail industry, a methodological departure from the narrower analytical frameworks commonly observed in prior works. This innovative approach not only highlights key players and influential communities but also sheds light on the intricate interplay of collaboration and technological diffusion across the sector. Unlike previous studies that often focus on isolated technological applications, this research offers a comprehensive examination of a spectrum of technologies such as AI, IoT, blockchain, and AR/VR, and their interconnected impacts, thereby providing a holistic understanding of the technological evolution within the industry. Furthermore, the in-depth use of patent mining to uncover emerging technologies and gain competitive insights significantly advances the existing literature, which typically utilizes patent data in limited contexts. This study extends beyond mere academic analysis, offering practical, strategic insights that are directly applicable to a wide array of industry stakeholders including large corporations, SMEs, startups, and policymakers, thus addressing critical gaps in understanding strategic technology integration. The necessity of this research is underscored by the ongoing rapid technological transformations and competitive pressures in the retail sector, making it a timely study that provides stakeholders with a robust framework to leverage innovations for competitive advantage and sustainable growth. This paper makes a substantial contribution to both academic literature and practical applications in the field of retail technology, marking a significant step forward in the comprehensive understanding of retail innovations and strategic decision-making in an increasingly digital marketplace.

III. METHODOLOGY

This research examines inventions in the field of retail to understand the types of technologies and the main groups of actors in this industry. This method consists of several interconnected steps along two parallel analytical paths, which are

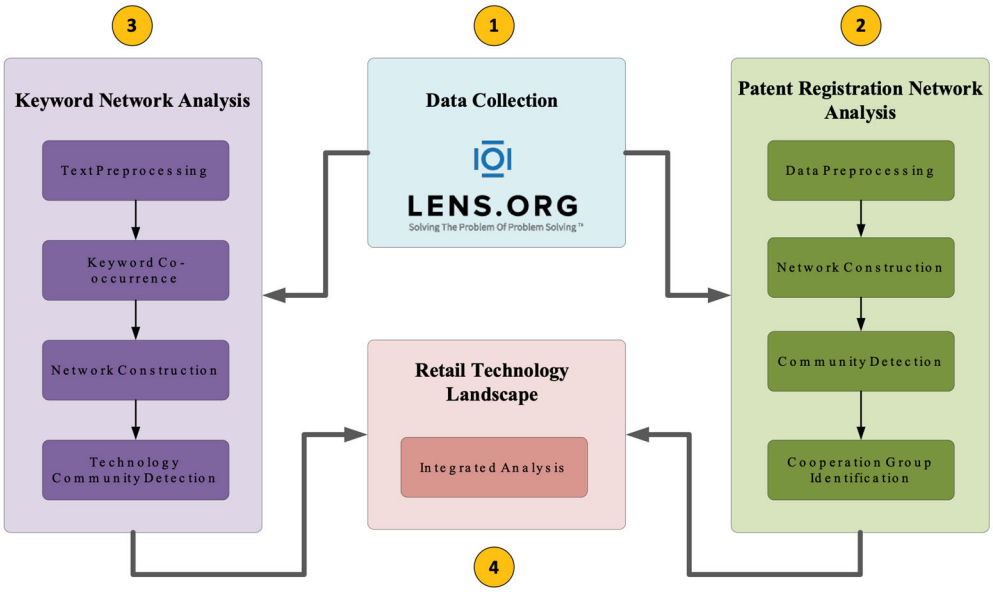


FIGURE 1. Research methodology.

shown in FIGURE 1. To analyze the collaborative network structure within retail patent data, we applied the **Louvain method** for community detection, a widely-used algorithm that identifies communities based on modularity optimization. The Louvain algorithm operates through a two-phase iterative process. Initially, each node is assigned to its own community. In the first phase, nodes are moved to neighboring communities if such a move increases the modularity—a measure of the density of connections within communities relative to connections between communities. This phase continues until no further modularity gains can be achieved. In the second phase, each detected community is condensed into a "super-node," creating a new network level where the process repeats. This multi-level approach continues iteratively until maximum modularity is achieved and no more significant changes occur in the community structure [42], [121], [122].

The Louvain method's computational efficiency makes it suitable for large networks like our retail patent dataset. This algorithm was implemented using **Gephi**, a powerful software for network analysis and visualization, allowing for an intuitive representation of communities within the network. Gephi's implementation of the Louvain method enabled us to accurately detect key communities, revealing clusters that represent areas of concentrated innovation and collaboration among entities [123], [124]. This method provided a robust framework to uncover structural patterns within the retail technology network, supporting our analysis of strategic interactions and influential nodes.

A. DATA COLLECTION

The first step involved collecting patent data related to the keyword "retail" from a prominent patent reference site called LENS. This platform is widely used by researchers for patent analysis across various fields, providing comprehensive and reliable data for academic studies [125].

TABLE 3. Table of cooperation communication.

Source	*Target*	*weight*
FENG BRYAN	SERELL JANINE	1
FENG JUN	WEI JIANBIN	1
FENG WEIJIA	LAI QUANYING	1
FERRERO SPA	SOREMARTEC SA	2
FEUERBORN THOMAS C	J C PENNY CORP INC	1
FINCHAM CARSON C K	WALKER JAY S	3

B. PATENT REGISTRATION NETWORK ANALYSIS

1) DATA PREPROCESSING

The collected data was preprocessed to identify connections between individuals and companies in patent registration. This step aimed to uncover the pairwise relationships in patent registration cooperation. The output of this preprocessing step is represented in Table 3, which shows the relationships between entities in patent registration.

2) NETWORK CONSTRUCTION AND VISUALIZATION

Based on the preprocessed data shown in Table 3, a network of connections was created and visualized. In this network, individuals or companies active in patent registration were designated as nodes, and their cooperation in patent registration acted as edges. The weight of each edge was determined by the frequency of joint patent registrations between the connected entities.

The network was constructed and visualized using Gephi. This powerful software is a great tool for network analysis and visualization [122]. Gephi allowed for an intuitive representation of the complex relationships within the patent registration landscape [126]. The software's force-directed layout algorithms were employed to position nodes in a way that minimized edge crossings and emphasized structural patterns in the network [127].

3) COMMUNITY DETECTION

To identify cooperation groups in patent registration, community detection analysis was performed on the network. The Louvain method, based on modularity optimization, was employed for this purpose. Modularity, as defined by Newman [128], measures the effectiveness of network clustering. The algorithm works iteratively, as illustrated in Figure 2:

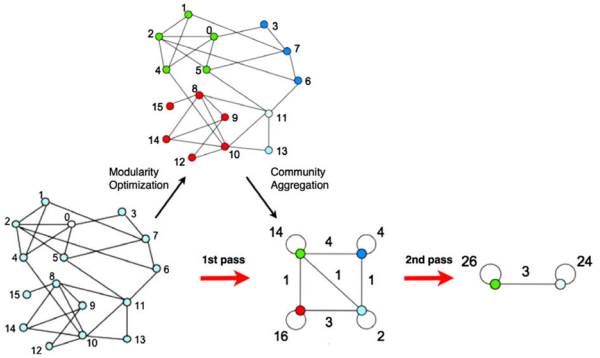


FIGURE 2. Community detection based on increasing modularity [129].

Initially, each node is considered a separate community.

For each node, the algorithm examines if moving it to a neighboring community would increase the modularity. This process continues until no further improvements in modularity are possible [130].

In the second phase, the algorithm merges smaller communities into larger ones to further increase modularity. Both phases continue until the community structures stabilize and modularity reaches its peak.

4) COOPERATION GROUP IDENTIFICATION

Based on the entities present in each detected community, cooperation groups were identified and named, providing insights into the key collaborative clusters in the retail technology patent landscape.

C. KEYWORD NETWORK ANALYSIS

1) TEXT PREPROCESSING AND KEYWORD EXTRACTION

The abstract text of each patent underwent a series of preprocessing steps to prepare it for keyword extraction. This process was implemented in Python, utilizing several specialized libraries for natural language processing. The key steps and libraries used were:

- Text Cleaning: Regular expressions (re library) were used to remove numbers, punctuation, and extra whitespace from the text.
- Lowercasing: All text was converted to lowercase to ensure consistency.
- Stop Word Removal: Common words that do not contribute significantly to the meaning (e.g., "the", "is", "at") were removed using the NLTK (Natural Language Toolkit) library's English stop words list.
- Lemmatization: Words were reduced to their base or dictionary form using NLTK's WordNetLemmatizer. This step helped in standardizing word forms and reducing vocabulary size without losing semantic meaning.
- Keyword Extraction: After preprocessing, the 30 most frequent words in each patent abstract were extracted as keywords. This was accomplished using Python's collections Counter class, which efficiently counts item frequencies.

This comprehensive preprocessing and keyword extraction approach ensured that the most relevant and meaningful terms were identified from each patent abstract, forming a solid foundation for subsequent network analysis.

2) KEYWORD CO-OCCURRENCE ANALYSIS

A correlation table of keywords was created, with columns for source keyword, target keyword, and the weight of their relationship. This weight represented the frequency of co-occurrence of keyword pairs in patent abstracts. The resulting co-occurrence data is represented in Table 4.

TABLE 4. Keyword Co-occurrence.

Source	*Target*	*weight*
crossbar	support	4
crossbar	tubular	3
crossbar	upright	8
crossborder	ecommerce	4
crowd	region	5
crowd	target	3
crust	edge	4

3) KEYWORD NETWORK CONSTRUCTION

Based on the co-occurrence data shown in Table 4, a network of keywords was constructed using Gephi. In this network, keywords formed the nodes, and their co-occurrences formed the edges. The edge weights were determined by the frequency of co-occurrence, allowing for a nuanced representation of the strength of relationships between different technological concepts.

4) TECHNOLOGY COMMUNITY DETECTION

The community detection algorithm was applied to the keyword network to identify clusters representing different technology types in the retail industry. This step employed

the same modularity-based approach used in the patent registration network analysis, leveraging Gephi's implementation of the Louvain method.

5) TECHNOLOGY TYPE IDENTIFICATION

Each detected community in the keyword network was analyzed and labeled based on its constituent keywords, representing distinct technology types in the retail sector. This process involved both quantitative analysis of the most central or frequent keywords in each community and qualitative interpretation based on domain expertise.

D. INTEGRATED ANALYSIS

The final step involved an integrated analysis of the patent registration cooperation groups and the identified technology types. This analysis examined which retail technologies each influential group focused on documenting, providing insights into collaboration patterns, investment trends, and innovation focus areas in the retail technology landscape.

This comprehensive methodology combines network analysis techniques with advanced text mining to provide a nuanced understanding of both the key actors and the emerging technological trends in the retail patent ecosystem. By leveraging both quantitative data processing and qualitative expert interpretation, this approach offers a robust framework for analyzing complex patent landscapes.

IV. RESULTS

A. DATA COLLECTION

The dataset required for this study has been collected using the LENS (Literature and Latte Exploration Networked Science) platform. Using the LENS platform, a keyword search in the academic literature related to the retail sector was conducted, primarily focusing on works that provided a systematic review of the retail industry [19], [27], [29], [30], [120]. Specifically, the search targeted patents containing terms such as ''retail,'' ''retail technology,'' and ''retail security.'' This search resulted in a total of 36411 patents. The search was conducted on July 6, 2024, which is the reason why the data collected for the year 2024 was less than anticipated.

The dataset for patents in the retail business dates back to 1995, as seen in Figure 3. This figure depicts the annual total of registered patents, specifically highlighting the emergence and recent growth of patent registrations in the retail sector.

B. CHARACTERISTICS OF THE RETAIL INDUSTRY PATENT REGISTRATION NETWORK

To gain a deeper comprehension of the characteristics of the collaborative network established by participants in the Retail industry patent registration, which is shown in Table 5, some essential metrics were computed. These metrics provide valuable information about the network's configuration and behavior:

- **Average Degree:** This network's average degree is 3.6. This indicates that each entity or person in the network, on average, has a connection with 3.6 other entities or individuals. This metric provides an overall picture of the level of interconnectedness inside the network. The 3.6 result indicates a moderate level of connectivity in the retail industry's patent registration network.

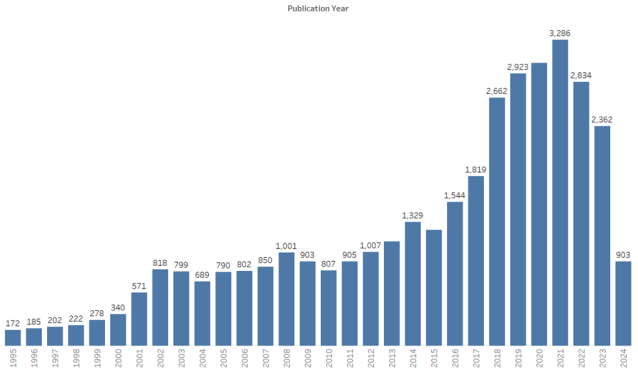


FIGURE 3. Number of patents by year of publication.

- **Density:** The network has a density of 0.000, density indicating the ratio of actual collaborations to the total possible collaborations. A lower density highlights the existence of specialized groups by indicating the lack of interconnection among all participants.
- **Number of Components:** The retail industry patent registration participant network consists of 2092 components, indicating that the network is organized into 2092 distinct clusters or groups of participants. Each group represents a distinct subset of participants connected by shared patent registrations or cooperation. Nevertheless, there is a lack of connection among participants belonging to different categories. These findings indicate that the patent registration landscape in the retail industry is characterized by a high degree of fragmentation, with numerous distinct clusters of activity. Each component can represent either an individual entity working alone or a group of participants working closely together but without any connections to other clusters in the network.
- **Average Clustering Coefficient**: The average clustering coefficient of this network is 0.928. The clustering coefficient of a node measures how interconnected its neighbors are. Specifically, it represents the likelihood that two neighbors of a node are also neighbors of each other, forming a triangle. The number of 0.928 is quite high, indicating that the network is highly clustered. This suggests that, on average, the neighbors of a node are very likely to be connected to each other, forming dense clusters or communities. Having 24,368 triangles, which are a set of three nodes that are all connected to each other, means that there are 24,368 sets of three nodes that are all mutually connected. This further confirms the high level of clustering in the network.

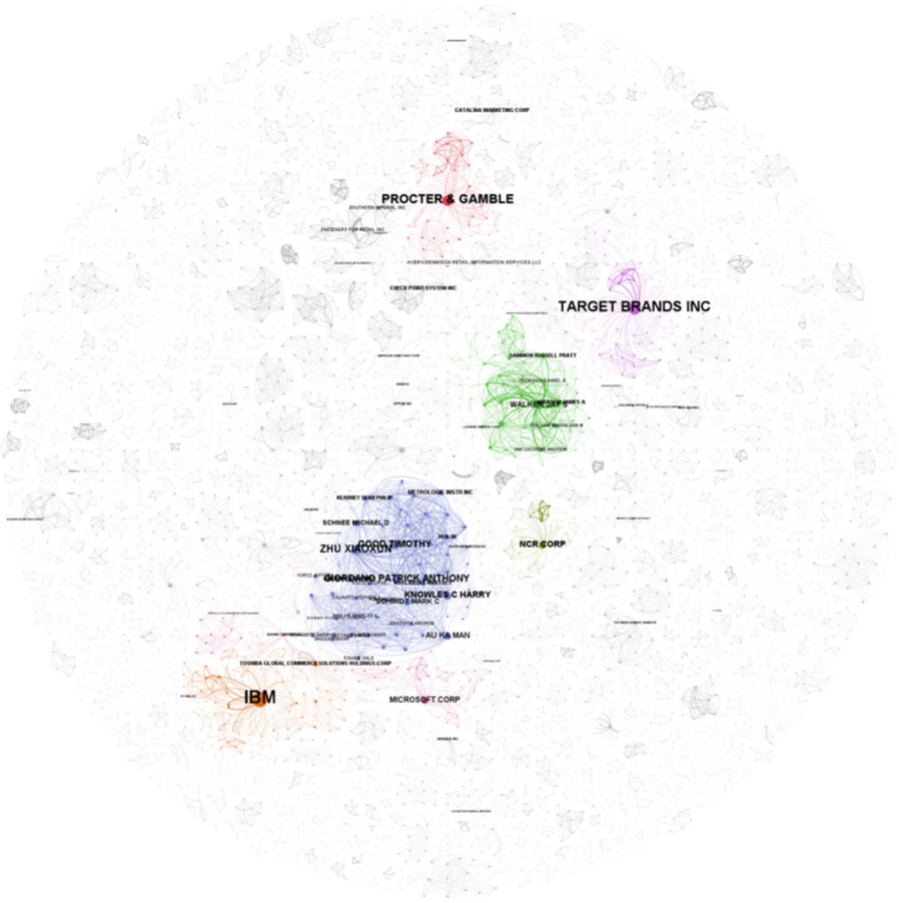


FIGURE 4. Collaborative network.

C. FORMATION OF THE RETAIL INDUSTRY PATENT REGISTRATION NETWORK

To shed light on the retail industry patent registration network, all active individuals or entities involved in the registration process of the patents collected were extracted from the dataset. As Figure 4 illustrates, that these participants create a collaborative network, with 8225 entities or individuals actively participating in the patent registration of the retail sector. Every participant in the network is represented by a node, and the edges connecting the nodes indicate the collaborative relationships between members.

Among these 8225 entities or individuals, a significant number of 14805 collaborative relationships were identified. These collaborations demonstrate the level of cooperation among individuals and companies in the retail industry patent registration community throughout time.

The 7 communities that had more than 0.5% of the participants in the retail industry patent registration network have been recognized and are illustrated in the Figure 5. These communities represent significant clusters within the network, indicating areas where participants are more densely connected, likely reflecting key players, collaboration hubs, or influential groups within the retail industry's patent ecosystem. The detailed breakdown of these communities, including the percentage of participants and their characteristics, is presented in the Table 5, providing insight into the structure and dynamics of the network.

The following provides an in-depth analysis of the seven principal communities within the retail industry patent registration network, accompanied by a comprehensive explanation of each:

1) COMMUNITY 92: RETAIL INNOVATION SYSTEMS

This community is composed of prominent inventors, including Walker Jay S., Jorasch James A., and Tedesco Daniel E., who have made substantial contributions to the patent landscape in retail technology. Their collaborative efforts have led to the development of numerous patents focused on innovative retail systems. The designation "Retail Innovation Systems" is derived from the community's concentrated efforts on creating and patenting advanced technologies that revolutionize traditional retail operations. The patents

TABLE 5. Main communities of participants.

Community Number	*Main members*	*Suggested name*	*rationale*
92	• WALKER JAY S • JORASCH JAMES A • TEDESCO DANIEL E • MUELLER RAYMOND J • VAN LUCHENE ANDREW • LUCHENE ANDREW S VAN	Retail Innovation Systems	This group has a strong emphasis on cutting-edge retail systems and technology, as evidenced by the fact that numerous members possess multiple patents. The names imply a united group collaborating on sophisticated retail solutions.
1306	• ZHU XIAOXUN • AU KA MAN • KNOWLES C HARRY • SCHMIDT MARK C • GIORDANO PATRICK ANTHONY • GOOD TIMOTHY	Retail Scanning and Data Capture Technologies	A significant number of these individuals are affiliated with organizations such as Metrologic Instruments, a company that specializes in retail applications of barcode scanning and data capture technology.
184	• IBM • MOSKOWITZ PAUL A • LI TA-HSIN • STERN EDITH H • PICKOVER CLIFFORD A	AI and Analytics for Retail	This group is likely centered around advanced data analysis and artificial intelligence applications in the retail industry, with IBM being a prominent player and individuals known for their expertise in analytics and AI.
1231	• TARGET BRANDS INC • GOURLEY CHAD R • KORTH-MCDONNELL PATRICIA • NATIONS GREGORY M • STEWART JOE	Retail Brand Experience and Operations	Given Target Brands Inc.'s prominent role, this community prioritizes the enhancement of retail brand experiences and the improvement of retail operations.
99	• PROCTER & GAMBLE • SHERMAN FAIZ FEISAL • UNIV TSINGHUA • CHEN JIE • DU MINCHEN	Consumer Goods Retail Innovation	This community centers around advances in consumer goods retailing, with a strong emphasis on collaboration with academic institutions and the active involvement of Procter & Gamble as a significant member.
886	• MICROSOFT CORP • HUANG XUEDONG D • DAVIS MARC E • DYOR MATTHEW G • GERRITY DANIEL A	Digital Retail Platforms and Voice Technology	Microsoft's participation implies a concentration on digital platforms for retail, whilst members such as Huang Xuedong are recognized for their expertise in speech recognition, suggesting potential uses in voice-assisted shopping or customer service.
1495	• NCR CORP • BRACKENRIDGE STEPHANIE LEE • SRINIVASAN VIKRAM • STOPLIFT INC • MIGDAL JOSHUA	Retail Transaction and Loss Prevention Systems	NCR specializes in point-of-sale systems, whereas StopLift primarily focuses on retail loss prevention. This community is focused on solutions that enhance transaction processing and mitigate retail theft.

associated with this group likely encompass a wide array of innovations, ranging from enhanced point-of-sale systems to integrated retail management solutions. This name reflects their central role in driving technological advancements that enable more efficient, sophisticated, and customer-centric retail environments, positioning them as key contributors to the evolving retail ecosystem.

2) COMMUNITY 1306: RETAIL SCANNING AND DATA CAPTURE TECHNOLOGIES

The members of this community, including Zhu Xiaoxun and Knowles C. Harry, are primarily affiliated with Metrologic Instruments, an organization known for its expertise in barcode scanning and data capture technologies. The community's patenting activities are heavily focused on innovations that improve the efficiency and accuracy of data collection in retail settings. The term ''Retail Scanning and Data Capture Technologies'' properly captures the essence of their contributions, as their patents likely include advancements in barcode scanning, optical recognition, and data processing technologies. These innovations are crucial for enhancing inventory management, checkout processes, and overall operational efficiency in retail environments. This community's work underpins the technological foundation that supports the seamless operation of modern retail systems, making them integral to the retail industry's technological infrastructure.

3) COMMUNITY 184: AI AND ANALYTICS FOR RETAIL

Led by IBM, this community includes significant contributors such as Moskowitz Paul A. and Li Ta-Hsin, who are recognized for their expertise in artificial intelligence (AI) and data analytics. The community's focus on patenting technologies related to AI and analytics within the retail sector is encapsulated in the name ''AI and Analytics for Retail.'' This title reflects the community's pivotal role in advancing the use of AI to enhance decision-making processes, optimize supply

chain management, and personalize customer experiences in retail. The patents produced by this community likely cover innovations in machine learning algorithms, predictive analytics, and AI-driven customer insights, all of which are critical for driving efficiency and innovation in the retail industry. Their contributions significantly shape the integration of AI technologies into retail, enabling more intelligent, data-driven operations that are essential for maintaining a competitive edge in the market.

4) COMMUNITY 1231: RETAIL BRAND EXPERIENCE AND OPERATIONS

This community, led by Target Brands Inc., and involving members like Gourley Chad R. and Stewart Joe, focuses on enhancing the retail brand experience and improving operational processes through innovative patents. The name ''Retail Brand Experience and Operations'' reflects the community's dual focus on developing patents that support both the enhancement of brand identity and the optimization of retail operations. The innovations from this community likely include patents on customer engagement technologies, store layout designs, and operational management tools, all aimed at creating a cohesive and efficient shopping experience. This community plays a critical role in defining how retail brands interact with consumers and manage their internal processes, ensuring that both aspects are aligned to deliver superior customer experiences and operational effectiveness.

5) COMMUNITY 99: CONSUMER GOODS RETAIL INNOVATION

This community includes influential entities such as Procter & Gamble and academic institutions like Tsinghua University, who collaborate to drive innovation in the consumer goods retail sector. The name ''Consumer Goods Retail Innovation'' highlights the community's focus on patenting new technologies and methodologies that transform how consumer goods are marketed, distributed, and sold. The patents associated with this community likely encompass a range of innovations, including new packaging solutions, retail formats, and consumer engagement strategies that enhance the consumer experience and streamline retail operations. This community's contributions are vital in advancing the consumer goods sector within retail, where innovation is crucial for meeting changing consumer demands and maintaining market competitiveness.

6) COMMUNITY 886: DIGITAL RETAIL PLATFORMS AND VOICE TECHNOLOGY

Microsoft Corp leads this community, which includes experts like Huang Xuedong D. and Davis Marc E., who specialize in digital platforms and voice recognition technologies. The name ''Digital Retail Platforms and Voice Technology'' is indicative of the community's efforts to patent technologies that drive the digital transformation of retail. Their work likely involves innovations in creating seamless digital platforms that integrate online and in-store shopping experiences, as well as voice-assisted technologies that enhance customer interactions. These patents are critical in shaping the future of retail, where digital and voice technologies play an increasingly central role in how consumers interact with retail environments. The community's contributions are fundamental in creating the next generation of retail technologies, making them key players in the ongoing digitalization of the industry.

7) COMMUNITY 1495: RETAIL TRANSACTION AND LOSS PREVENTION SYSTEMS

This community includes significant contributors such as NCR Corp and StopLift Inc., who focus on securing and optimizing retail transactions through innovative patenting. The name ''Retail Transaction and Loss Prevention Systems'' captures the essence of their work, which centers on developing patents that enhance the security and efficiency of retail transactions. Their innovations likely include advancements in point-of-sale systems, fraud detection technologies, and loss prevention solutions that are essential for protecting retail revenue and ensuring smooth transactional processes. The patents from this community are critical for maintaining the integrity of retail operations, making them indispensable in the broader retail patent network. Their contributions help safeguard retail environments, ensuring that both retailers and consumers can trust the transaction process.

D. KEYWORDS NETWORK

In the process of the investigation of the retail industry patenting cooperation network, we performed community detection on this network due to its significant role in extracting the complex lineage of patents in this field. Figure 5 depicts the creation of a genealogy by tracing the communication network of keywords contained in the patents. Community detection in the field of retailing involves the identification of separate groups and communities of similar terms within the network [131].

This network consists of 5505 nodes, each representing a unique keyword pertinent to retail-related technologies. These nodes are interconnected by 130320 edges, indicating relationships such as co-occurrences within patents. The substantial number of edges underscores a highly interconnected network, suggestive of a complex and well-established technological ecosystem within the retail domain. The **average degree** of the network, calculated at 47.389, further highlights the high level of connectivity between keywords. On average, each keyword is associated with approximately 47 other keywords, reflecting a dense web of interrelations within the technological discourse of the retail sector. Despite this interconnectedness, the network's overall **density** is measured at 0.009, which suggests that while certain clusters within the network are tightly connected, the network as a whole remains relatively sparse. This sparsity

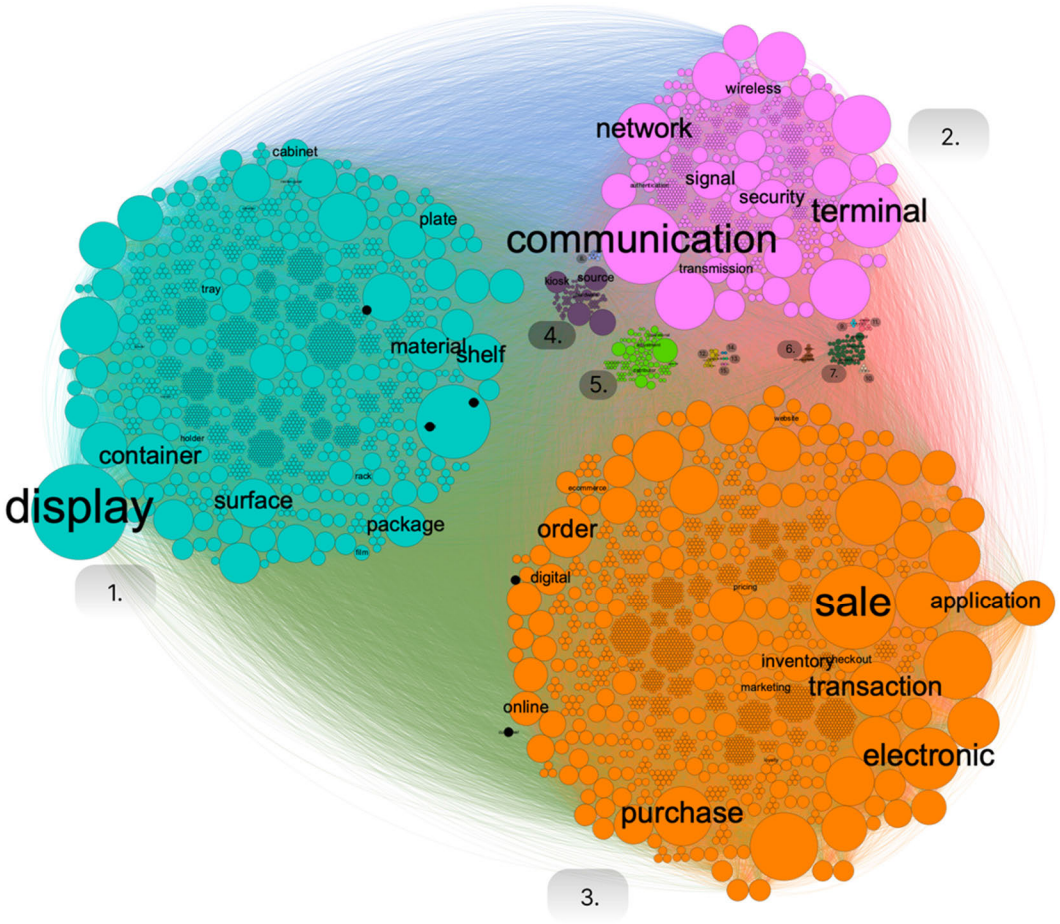


FIGURE 5. The results of community detection.

may indicate that, although there are areas of concentrated innovation, many keywords do not directly interact with the broader network. The **average clustering coefficient** of 0.813 points to a high degree of local interconnectedness within these clusters, meaning that within individual clusters, keywords tend to group together, forming tightly knit communities of related technologies. The presence of densely connected clusters and a high average degree of interconnection suggests the existence of technological hotspots within the sector. These hotspots are likely areas where innovation is concentrated and where significant future developments are anticipated. The retrieved communities are essentially groups of keywords that exhibit the strongest semantic links. This suggests that they represent common topics, themes, or areas of technology in the retail sector.

Each extracted community receives a specific color code, as shown in Figure 5. The use of color-coding facilitates the visual distinction between each cluster, aiding the viewer in differentiating them visually. This method of selective coloring allows us to concentrate on the most significant and widespread groupings of keywords, offering useful insights into the leading themes and subfields within the patent landscape of the retail industry.

Table 6 presents comprehensive data regarding the members of the primary established communities:

After analyzing the keywords and themes that arise from the community identification in the network of patents within the retail industry, suitable names for each community have been identified. Specific criteria have guided the selection of these names:

1) LIGHT BLUE COMMUNITY: RETAIL PRODUCT DISPLAY AND PACKAGING SOLUTIONS

This community comprises a vast array of inventions intended for enhancing product display and packaging. This community holds patents related to the organization

TABLE 6. Details of the main communities.

color	*Percentage of members to total*	*Percentage of edges to total*	*The most important keys*	*Community name*
Light blue	41.962%	41.665%	"container", "shelf", "display", "package", "box", "tray", "rack", "holder", "cabinet", "material", "surface", "plate", "film", "sheet", "label"	Retail Product Display and Packaging Solutions
Light pink	14.496%	10.048%	"Network", "wireless", "communication", "signal", "transmission", "encryption", "authentication", "protocol", "security", and various technical terms like "LTE", "5G", "WIFI", "Bluetooth"	Retail Communication and Security Technologies
orange	39.055%	47.254%	"sale", "purchase", "transaction", "customer", "order", "checkout", "inventory", "pricing", "loyalty", "marketing", "digital", "online", "electronic", "application", "website", and "e-commerce"	Core Retail Operations and Digital Commerce
violet	1.108%	0.217%	"kiosk", "hardware", "source", "atm", and "terminal"	Retail Technology Hardware and Infrastructure
Light green	1.671%	0.444%	"distributor", "adjustment", "wearer", "polyphenols", "transresveratrol", and "operational"	Specialized Retail Services and Consumer Goods
brown	0.163%	0.037%	"simultaneously", "absorbs", "amenity", "cabin", "passenger", and "monument"	Retail Space Optimization and Customer Experience
Dark green	0.745%	0.186%	"conventional", "convey", "imagery", and "multipart"	Retail Data Processing and Analysis
light blue	0.145%	0.036%	"affordable", "arcade", "console", and "joystick"	Retail Entertainment and Gaming Solutions
cyan	0.073%	0.008%	"cooccurrence", "cooccurrences", "coa", and "cob"	Retail Product Composition and Manufacturing
beige	0.109%	0.019%	"backscatter" and "channel"	Retail RFID and Tracking Technologies
Hot Pink	0.145%	0.028%	"vicinity", "indoor", and "microclusters"	Retail Location and Proximity Services
Gold	0.218%	0.054%	"consent", "consent specific", "user-specific", "vault", and "drawback"	Retail Data Privacy and Consent Management
Lime Green	0.036%	0.001%	"flour" and "noodle"	Specialized Food Retail
turquoise	0.036%	0.001%	"lease" and "lessee"	Retail Leasing Solutions
Dark pink	0.036%	0.001%	"underwear" and "panty"	Intimate Apparel Retail

of displays, shelves, racks, holders, and cabinets. These mechanisms are particularly important in terms of increasing product exposure and convenience in retail environments. In addition, it includes innovations in packaging concerning containers, boxes, trays, and holders, all of which play a vital role in safeguarding products, facilitating their transportation, and enhancing their visual identity. It also focuses on the developments in materials and methods for surfaces, plates, films, sheets, and labels that are essential for packaging since they provide protection, ecological compatibility, and clear information to the customers. Altogether, these patents reflect certain advancements in the improvement of the function, performance, and aesthetic appeal of retail product display and packaging systems.

2) LIGHT PINK COMMUNITY: RETAIL COMMUNICATION AND SECURITY TECHNOLOGIES

This community comprises patents that significantly contribute to the current retail framework, specifically in the areas of communication and security. Keywords like 'network', 'wireless', 'communication', 'signal', 'transmission', 'encryption', 'authentication', and 'protocol', together with terms like 'LTE', '5G', 'WiFi', and 'Bluetooth', highlight the importance of fast and reliable networks and strong security measures. These patents relate to the wireless networks, signals, and data security that ensure the efficiency and security of the retail business. These solutions include approaches to ensure high connectivity and exclude unauthorized access, which is crucial for safeguarding transactional information. This community consists of the integration of advanced

communication and security technologies needed to enhance the retail industry's operations.

3) ORANGE COMMUNITY: CORE RETAIL OPERATIONS AND DIGITAL COMMERCE

This community encompasses a cluster of patents focused on fundamental and disruptive aspects of the retail industry. This community includes comprehensive coverage of both traditional retail operations and the evolving digital commerce landscape. The patents filed by this community relate to the new transactional process, customer interaction and engagement, inventory, and pricing strategies. Additionally, this community expresses the continuity of the digital revolution and the use of online platforms, focusing on electronic and online applications, websites, and e-commerce solutions. All these innovations play a critical role in increasing operational effectiveness, customer satisfaction, and competitive advantage in the retail industry.

4) VIOLET COMMUNITY: RETAIL TECHNOLOGY HARDWARE AND INFRASTRUCTURE

This community includes innovations related to the physical and digital interfaces facilitating retail transactions. This community mainly comprises the patents associated with the devices and systems designed for retail customer interaction and transaction processing. This category of patents outlines the invention and improvement of self-service terminals, POS, ATMs, and other physical facilities that enable outlets. These innovations are central to the process of using efficiency, user experience, and transactional data management to make the retail business more modern. Such technologies are crucial for streamlining operations, reducing labor costs, and enhancing customer satisfaction through improved service delivery mechanisms.

5) LIGHT GREEN: SPECIALIZED RETAIL SERVICES AND CONSUMER GOODS

The Specialized Retail Services and Consumer Goods community encompasses innovations related to retail distribution processes and specialized consumer products. The keywords ''distributor'' and ''operational'' indicate a focus on logistical and operational improvements within the retail sector, involving methods for efficient distribution and inventory management. Keywords such as ''adjustment'' and ''wearer'' address consumer-centric product enhancements, particularly in wearable goods that require personalized adjustments for an optimal user experience. ''Polyphenols'' and ''transresveratrol'' signify a segment dedicated to health-oriented consumer products, particularly those incorporating these compounds known for their antioxidant properties. This community merges innovations in the distribution of specialized retail services with advancements in consumer goods that emphasize health and personalized use.

6) BROWN COMMUNITY: RETAIL SPACE OPTIMIZATION AND CUSTOMER EXPERIENCE

Patents associated with the strategic design and improvement of retail environments are included in this community. The primary objective is to optimize operational efficiency and consumer satisfaction by integrating a variety of functional and visual elements. The patents in this community focus on improvements in spatial design, such as multifunctional fixtures and adjustable layouts that enhance space use and enhance interactions with customers. Keywords such as ''cabin'' and ''monument'' highlight the creation of thematic or immersive surroundings within retail venues, with the goal of generating captivating and unforgettable shopping experiences. In general, the patents of this community prioritize achieving a harmonious combination of space optimization and enhanced customer experiences by means of well-considered design and functional improvements in retail environments.

7) DARK GREEN COMMUNITY: RETAIL DATA PROCESSING AND ANALYSIS

The Retail Data Processing and Analysis community comprises patents that specifically address traditional techniques for processing and analyzing retail data. The keywords ''imagery'' and ''multipart'' show that these patents involve well-established methods for data handling, data transmission or communication, the utilization of visual imagery for data analysis, and the administration of various data components. These patents encompass technologies and systems specifically developed for the purpose of handling retail data using conventional methods, facilitating data exchange, employing visual aids for enhanced interpretation, and integrating several data streams for thorough analysis.

8) LIGHT BLUE COMMUNITY: RETAIL ENTERTAINMENT AND GAMING SOLUTIONS

The patents associated with the incorporation of interactive gaming elements within retail environments are included in this community. The terms ''affordable,'' ''arcade,'' ''console,'' and ''joystick'' indicate a concentration on cost-efficient gaming technologies specifically created for commercial retail environments. This community focuses on advancements in consumer involvement through interactive entertainment systems. The patents in this community demonstrate progress in developing immersive and interactive shopping experiences, utilizing gaming features to improve client engagement and boost sales in retail businesses.

9) CYAN COMMUNITY: RETAIL PRODUCT COMPOSITION AND MANUFACTURING

This community includes patents that specifically address the incorporation and improvement of product compositions and manufacturing techniques in the retail sector. Among these innovations are patents for systems that maximize

profits through optimized pricing and promotion strategies, solutions for co-occurrence analysis of product attributes, and breakthroughs in food and product compositions that display unique, synergistic properties. These patents jointly seek to improve product development, increase production efficiency, and enhance market competitiveness by utilizing advanced data analysis and creative compositions.

10) BEIGE COMMUNITY: RETAIL RFID AND TRACKING TECHNOLOGIES

Patents related to retail radio-frequency identification (RFID) systems are included in this community. The keywords ''backscatter'' and ''cchannel'' pertain to distinct technical elements of RFID communication. ''Backscatter'' denotes the use of modulation for transmitting data from the tag to the reader, while ''cchannel'' refers to the application of channel coding for error correction in RFID systems. These patents specifically target the enhancement of inventory tracking, prevention of losses, and improvement of supply chain visibility in retail operations by utilizing modern RFID technologies.

11) HOT PINK COMMUNITY: RETAIL LOCATION AND PROXIMITY SERVICES

The Retail Location and Proximity Services community consists of patents that specifically address technology for accurate indoor location and targeted customer engagement in retail settings. The patents employ microclustering algorithms to examine client movement patterns and proximity to merchandise within stores. These technologies empower merchants to provide extremely customized, location-specific services and promotions to clients as they move through indoor retail areas.

12) GOLD COMMUNITY: RETAIL DATA PRIVACY AND CONSENT MANAGEMENT

This community comprises patents that specifically address consent procedures tailored to individual users and the secure storage of data within the retail industry. The patents in this group focus on the installation of permission management systems, user choice controls, and data vaults to improve privacy compliance and safeguard customer information. These technologies seek to address the limitations of conventional data collection methods by offering detailed consent choices and secure storage solutions for sensitive consumer data in retail settings.

13) LIME GREEN: SPECIALIZED FOOD RETAIL

This community contains patents that are connected to the manufacturing and sale of niche food items. This community encompasses advancements in the manufacture, packaging, and sale of various food goods. It represents a specialized sector within the food retail industry that concentrates on these particular food items. The patents within this community play a role in driving progress in the field of food technology, improving the quality of products, extending their shelf life, and increasing convenience for consumers.

14) TURQUOISE COMMUNITY: RETAIL LEASING SOLUTIONS

This community includes patents that specifically pertain to advancements in retail property lease agreements and technologies. The patents in this group focus on techniques for simplifying lease negotiations, enhancing tenant-landlord interactions, and creating digital platforms for overseeing commercial real estate agreements in the retail industry.

15) DARK PINK COMMUNITY: INTIMATE APPAREL RETAIL

The Intimate Apparel Retail community includes patents that pertain to the creation, production, and sale of undergarments. The patents in this category mostly concentrate on advancements in materials, construction methods, and retail strategies that are uniquely tailored for underwear and panties. This highlights the distinctiveness of this particular niche within the wider retail sector.

E. VALIDATION OF THE METHOD ON AN ADDITIONAL DATASET

To ensure the robustness and general applicability of the proposed methodology, we conducted a validation study by applying our community detection approach to a secondary dataset from a distinct but similarly structured industry: **the pharmaceutical patent sector**. This dataset, sourced from the same patent database (LENS), comprised **28,536 patents** filed between 1995 and 2024, with **7,142 distinct entities** and a total of **13,456 collaborative links** representing patent co-authorship and co-assignee relationships. This dataset was selected to mirror the structure and complexity of the retail dataset, while introducing variation in industry-specific innovation patterns and collaboration structures.

Using the Louvain method for community detection, as previously applied to the retail patent data, we followed identical preprocessing steps, including normalization of patent metadata and construction of the collaboration network graph based on entity connections. The analysis was executed in **Gephi** using the same modularity optimization thresholds, allowing for a direct comparison of results across datasets.

The application of our methodology to the pharmaceutical dataset resulted in a modularity score of **0.72**, closely matching the modularity score observed in the retail dataset (0.71), suggesting a comparable level of community structure and reinforcing the method's ability to detect meaningful collaboration clusters in large, industry-specific networks. The Louvain algorithm identified **13 main communities** within the pharmaceutical data, each containing significant technological focus areas such as drug formulation, biopharmaceuticals, and medical devices. This pattern is in line with the established domains in pharmaceutical innovation, further confirming that the community detection method accurately mapped the complex landscape of collaborative entities and innovation foci.

Quantitatively, the average degree within the pharmaceutical network was **3.77**, nearly identical to that observed in the retail network (3.6), indicating similar levels of entity connectivity across both datasets. Additionally, the clustering coefficient was calculated at **0.91** (compared to 0.928 in retail), suggesting a similarly high degree of local interconnectedness among nodes within communities. This consistency across both networks provides strong evidence of the method's reliability and generalizability.

The successful identification of coherent and industry-relevant communities within the pharmaceutical dataset demonstrates that the Louvain method and our approach to network construction are robust across sectors. These results underscore the methodology's ability to generalize beyond the retail industry, making it a viable tool for analyzing collaborative structures and technological domains across diverse innovation ecosystems. This cross-dataset validation strengthens the applicability of our findings, offering a versatile approach to community detection in patent networks and enhancing confidence in the method's capacity to support strategic analysis in varied technological landscapes.

V. DISCUSSION

The Sankey diagram as shown in Figure 6, visually captures the intricate flow of relationships between key players and various technological domains, offering a clear depiction of how major communities are interconnected with specific innovations. For instance, the ''Retail Innovation Systems'' community of participants, comprising influential figures like Walker Jay S. and Jorasch James A., shows the most significant connection to the ''Core Retail Operations and Digital Commerce'' technology area, focusing 49% of its total attention on this community, which makes ''Retail Innovation Systems'' the main investor of this community, having 31% of the total investments and focus of all participant communities on ''Core Retail Operations and Digital Commerce.'' These participants demonstrate a deep commitment to driving innovation in foundational retail technologies, presumably because of their substantial potential to transform retail experiences and operations. Similarly, communities like ''AI and Analytics for Retail,'' represented by industry giants like IBM, demonstrate strong ties to ''Core Retail Operations and Digital Commerce,'' with 42% of its total focus, and ''Retail Communication and Security Technologies,'' with 27% of its focus. This highlights the central role of advanced data analytics and artificial intelligence in shaping the future of retail, where personalization, efficiency, and informed decision-making are becoming increasingly important. The Sankey diagram further illustrates how some communities, such as Microsoft and other participants in ''Digital Retail Platforms and Voice Technology,'' bridge multiple technological categories by dividing their investments into multiple technology communities, such as ''Retail Product Display and Packaging Solutions'' and ''Retail Communication and Security Technologies.'' As illustrated on figure 6, most of the participant's communities have their main focus on the ''Core Retail Operations and Digital Commerce'' technologies, with ''Retail Innovation Systems'' contributing the most investments, as we already discussed, followed by ''AI and Analytics for Retail'' with a total of 24% of the whole ''Core Retail Operations and Digital Commerce'' tech scene. While not all participants follow this path, the ''Consumer Goods Retail Innovation'' community, comprising companies such as Procter & Gamble and individuals like Sherman Faiz Feisal, primarily focuses on ''Retail Product Display and Packaging Solutions,'' accounting for 43% of the participants' total focus. ''Retail Brand Experience and Operations'' with entities such as Target Brands Inc. follows the same path, with 40% of the focus on these technologies. On the other hand, the ''Retail Scanning and Data Capture Technologies'' community has its main focus on ''Retail Product Display and Packaging Solutions,'' with 38% of the total investments from the participant community.

As illustrated in Figure 6, out of the total 15 technology communities detected and recognized, the main participants in the retail industry only focused their investment on 7 of them, excluding the rest of the technological areas. This selective focus suggests a deliberate and strategic allocation of resources toward areas that offer the highest potential for innovation, market growth, and return on investment. By honing in on these key communities, participants are likely prioritizing technologies that are not only relevant to current market demands but also aligned with broader industry trends. The heavy investment in ''Core Retail Operations and Digital Commerce'' and ''Retail Communication and Security Technologies'' reflects the ongoing shift towards e-commerce, the increasing need for secure and efficient communication systems, and the demand for innovative in-store experiences. The emphasis on ''Retail Product Display and Packaging Solutions'' highlights the importance of commercial packaging and product presentation in the retail industry, since these solutions are crucial for attracting customers and streamlining storage and logistics. Moreover, future innovation is likely to find fertile ground in the chosen communities, which enhance operational efficiency, improve customer experience, and drive personalization in retail. The focus on these areas suggests that participants want to lead now and shape the retail industry's future. On the other hand, the technology communities that did not receive as much attention may be perceived as less critical at this time, or they may represent niche or emerging sectors where market demand is still uncertain. For example, areas like ''Intimate Apparel Retail'' or ''Specialized Food Retail'' might not be as universally relevant, or they may require more specific expertise that the participants do not currently possess. Alternatively, participants may revisit these neglected areas in the future once they have solidified the primary sectors, as they are still in the early stages of development and have not fully established commercial viability. The selective focus on these 7 technology communities also reflects the formation of collaborative ecosystems, where multiple participants work together or compete to drive rapid advancements within their

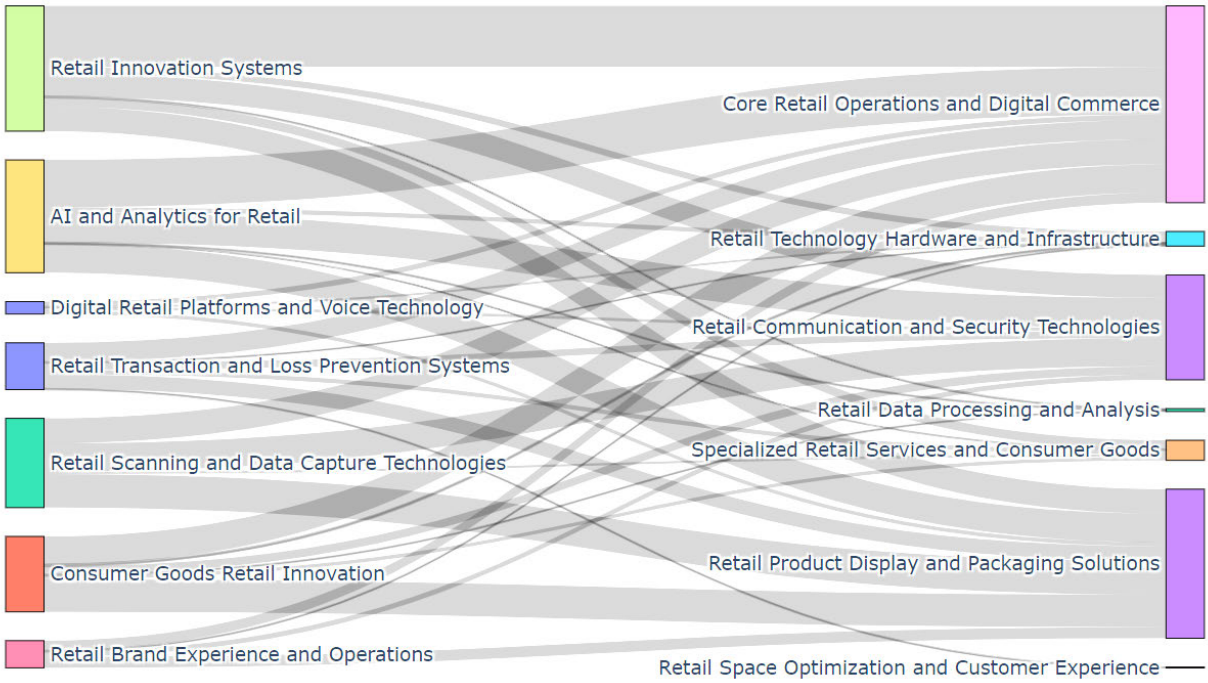


FIGURE 6. The amount of attention of participants community to each of the technology communities.

chosen fields. These ecosystems facilitate quicker adoption and scaling of new technologies, ensuring that the most promising innovations are brought to market efficiently and effectively.

Overall, this strategic concentration of efforts on a select number of technological communities underscores the participants' intent to maximize impact in the most promising areas of the retail industry. It highlights their desire to lead in innovation where it matters most, shaping the future of retail by investing in technologies that have the greatest potential to transform the industry. While some areas remain unexplored, this likely signifies a strategic approach, prioritizing the solidification of leadership in the most critical sectors before venturing into potentially less developed areas.

The identified patent patterns across major technological domains—such as AI, digital commerce, and secure communication—reveal key trends poised to shape the future of retail. For instance, patent activity in AI and data analytics suggests a growing emphasis on personalization and predictive modeling, which could significantly enhance customer experience and operational efficiency in retail. As these technologies advance, we can anticipate more granular customer insights and increasingly tailored marketing approaches, potentially redefining how retailers interact with and retain their customers.

The findings also bear strategic implications for stakeholders in the retail ecosystem. Large corporations, SMEs, and startups may all leverage insights from this study to better position themselves within the evolving landscape. For example, the dominance of secure communication patents implies an ongoing need for robust data privacy and cybersecurity measures, especially as customer data collection becomes more sophisticated. Startups can capitalize on these trends by innovating in areas like customer experience enhancement and secure transaction systems, while large corporations may prioritize strategic alliances with technology providers to stay at the forefront of these innovations.

In terms of potential challenges, the retail sector may encounter significant integration barriers as companies adopt and merge new technologies within their existing systems. For instance, incorporating IoT and AI solutions into traditional retail frameworks could involve complex adjustments in data handling, supply chain synchronization, and regulatory compliance. To address these challenges, retailers may need to adopt adaptive implementation strategies that focus on interoperability and scalable infrastructure, ensuring that new technologies can be effectively integrated without disrupting core operations.

Looking ahead, the pathways of retail innovation illuminated by this study's findings suggest several transformative directions. Increasing patent activity in AI-driven operations and customer interaction systems indicates a trend toward more automated and customer-centric retail models. Technologies such as virtual and augmented reality may also evolve to provide immersive, in-store-like experiences in digital settings. These developments point toward a future where retail is defined by highly adaptive, data-driven, and customer-focused strategies that enable retailers to maintain competitive advantage amid constant digital transformation.

Based on the results, we take a deep dive into the developments of this sector, offering tailored insights and actionable recommendations for various industry stakeholders. Addressing the needs of large corporations, SMEs, startups, policymakers, and more, this research offers strategic advice to leverage technological advancements for growth, innovation, and sustainable development in retail, while addressing instructions on future research and study limitations:

A. MANAGERIAL INSIGHTS AND IMPLEMENTATION

The rapidly evolving landscape of retail technologies presents both opportunities and challenges for a diverse range of stakeholders within the industry. As technologies such as AI, blockchain, IoT, AR/VR, and big data analytics continue to advance, organizations must strategically position themselves to harness these innovations effectively. This section provides detailed insights and actionable recommendations tailored to various groups, including large retail corporations, small and medium enterprises (SMEs), startups in retail technology, policymakers, and regulators, consumer advocacy groups, technology service providers, and academic and industry researchers. By focusing on these distinct groups, the discussion offers a comprehensive guide for leveraging technology to drive growth, foster innovation, and ensure the sustainable development of the retail sector.

Large retail corporations, with their substantial resources and market influence, are well-positioned to lead the technological transformation within the retail industry. These companies should focus on strategically integrating advanced technologies like AI, big data analytics, AR, VR, IoT, and blockchain into their operations. For instance, AI and analytics can be leveraged to personalize customer experiences and optimize inventory management, leading to improved customer satisfaction and operational efficiency. The implementation of AR and VR can create immersive shopping environments that engage customers and enhance brand loyalty. Additionally, blockchain technology offers an opportunity to improve supply chain transparency, ensuring product authenticity and enhancing consumer trust. IoT can further optimize supply chains by providing real-time monitoring and reducing inefficiencies. By adopting these technologies and focusing on innovation leadership, large corporations can not only improve their operational processes but also secure a competitive advantage in an increasingly digital retail landscape.

SMEs, despite having more limited resources compared to larger corporations, can still effectively leverage retail technologies to enhance their competitiveness and drive sustainable growth. For SMEs, the focus should be on adopting scalable, cost-effective technologies that offer flexibility and immediate benefits. Cloud computing and geolocation technologies, for example, can be crucial for managing data, optimizing operations, and targeting customers more effectively. SMEs should also explore collaborative innovation by partnering with technology providers or other retailers to access advanced technologies such as AI-powered chatbots and RFID systems without the need for significant upfront investment. Additionally, SMEs can differentiate themselves by targeting niche markets identified through patent mining, allowing them to avoid direct competition with larger retailers and carve out unique market positions. By strategically adopting technologies that align with their business goals, SMEs can enhance their market presence and operational efficiency.

Startups play a vital role in the retail industry by driving innovation and developing disruptive technologies that can redefine traditional retail practices. These agile organizations should focus on areas with high potential for disruption, such as AI-driven personalization, blockchain for secure transactions, and AR/VR for enhanced customer experiences. Startups can attract investment and accelerate their growth by developing innovative solutions that address pressing challenges in the retail sector. Forming strategic partnerships with established retailers can provide startups with market access, resources, and credibility, allowing them to scale their innovations more effectively. Moreover, startups must develop a robust patent strategy to protect their intellectual property, which is crucial for attracting investors and maintaining a competitive edge. By focusing on targeted innovation and leveraging partnerships, startups can play a significant role in shaping the future of retail technology.

Policymakers and industry regulators are instrumental in creating an environment that fosters innovation while ensuring fair competition and consumer protection. To support the adoption and development of the retail industry, policymakers should design policies that encourage innovation, such as providing tax incentives or grants for research and development, particularly for SMEs and startups. This can stimulate technological advancements across the retail sector and ensure that smaller players are not left behind. Additionally, clear regulatory frameworks for emerging technologies like AI, blockchain, and IoT are essential to ensure their ethical use and protect consumer rights. These frameworks should address critical issues such as data privacy and cybersecurity, which are becoming increasingly important in the digital retail landscape. Policymakers should also consider initiatives that support technological adoption among SMEs, such as offering training, resources, and subsidies. Such measures can promote a more inclusive technological advancement in the industry, benefiting the entire retail ecosystem.

Consumer advocacy groups have a vital role in ensuring that the adoption of new retail technologies aligns with consumer interests and protects their rights. As retailers increasingly implement technologies, it is essential to monitor their impact on consumer privacy, data security, and accessibility. Advocacy groups should work closely with policymakers and industry regulators to develop guidelines and standards that prioritize consumer protection. They should also educate consumers about their rights in the digital retail landscape, empowering them to make informed choices and ensuring that new technologies enhance rather than diminish the consumer experience. Additionally, these groups can

facilitate dialogue between consumers and retailers, ensuring that technological innovations are both consumer-friendly and ethical.

Technology service providers are the backbone of the retail industry's digital transformation, supplying the tools and platforms that enable the adoption of advanced technologies. These providers must focus on developing scalable, secure, and user-friendly solutions that address the specific needs of different retail segments, from large corporations to SMEs. Service providers should also prioritize interoperability and integration, ensuring that their technologies can seamlessly work with existing systems and other emerging technologies. By offering customizable solutions and maintaining a strong focus on customer support, technology service providers can help retailers effectively implement new technologies and maximize their return on investment. Additionally, staying ahead of industry trends through continuous innovation will allow these providers to offer cutting-edge solutions that keep their retail clients competitive in a rapidly evolving market.

Finally, **Researchers in academia and industry** play a crucial role in advancing the understanding of retail technologies and their impact on business practices. Interdisciplinary research that combines insights from technology, consumer behavior, and business strategy is essential for providing a holistic understanding of the implications of technological adoption in retail. Researchers should also focus on conducting longitudinal studies to assess the long-term benefits and challenges associated with specific technologies. Such research can guide retailers in making informed decisions about technology investments and help predict future trends in the industry. Collaborative research initiatives between academic institutions and industry players can bridge the gap between theory and practice, ensuring that research findings are directly applicable and beneficial to the retail sector. By engaging in these research activities, academics and industry researchers can contribute to the ongoing evolution of retail technologies and support the development of strategies that enhance the competitiveness and sustainability of the retail industry.

Totally, These findings offer specific, actionable insights for various retail stakeholders. **For retailers**, prioritizing investment in AI and data analytics is recommended to enhance customer personalization and operational efficiency, positioning them competitively within a data-driven market. **Technology providers** should focus on developing interoperable solutions that facilitate easy integration of emerging technologies (like IoT and blockchain) into existing retail infrastructures, thus enabling seamless technology adoption for clients. **Startups** in the retail tech space can leverage this research by targeting high-growth areas identified in patent trends, such as digital commerce and secure transaction solutions, to attract investment and strategic partnerships. Meanwhile, **policymakers** should consider fostering innovation-friendly regulatory frameworks, particularly in data privacy and cybersecurity, to support sustainable retail technology adoption. By addressing these strategic areas, each stakeholder group can better navigate the evolving landscape, optimizing technology investments and contributing to a more innovative and secure retail environment.

B. LIMITATIONS AND FUTURE RESEARCH

While the research offers useful insights on the subject, it is crucial to recognize its limits in order to fully comprehend the findings. By acknowledging these limitations, one can achieve a more sophisticated understanding of the findings and identify specific areas that require additional investigation. In addition, the identification of relevant areas for future research can assist researchers in expanding on the current study, and addressing unresolved inquiries. This ongoing investigation is crucial for the advancement of knowledge in the subject and for ensuring that future studies on the retail sector can make valuable contributions to the existing body of research. By considering these constraints and following novel avenues of inquiry, we can improve our comprehension and lay the groundwork for more resilient and influential discoveries in the future.

One significant limitation is the reliance on patent data, which may not capture all technological innovations in the retail industry. Patents often represent only a subset of advancements, as not all innovations are patented, and some patents may not be publicly accessible due to confidentiality or pending status. To address this, future research should incorporate additional data sources, like industry reports and market analyses, to provide a more comprehensive view of respondents. Another limitation is the temporal lag in patent data, which can cause the analysis to not reflect the most current trends or emerging technologies. Future research could employ real-time data analytics to capture emerging trends and technologies more effectively, thus reducing the temporal lag in patent data. Additionally, while SNA provides insights into the relationships and connections within patent registrations, it does not fully capture the qualitative impact or strategic importance of individual patents. Future studies should combine SNA with qualitative research methods, such as expert interviews and case studies, to gain deeper insights into strategic technologies. The study also covers the retail industry broadly, overlooking specific trends and technological needs unique to sub-sectors such as e-commerce or brick-and-mortar retail. Conducting detailed studies on specific retail sub-sectors can yield more targeted insights, addressing unique technological challenges and opportunities. Furthermore, the study does not cover all relevant technologies equally, potentially missing out on emerging technologies that are not yet widely recognized or adopted. Future research should focus on identifying and analyzing these emerging technologies that have the potential to disrupt the industry. Lastly, the study does not consider interdisciplinary influences where technologies from other fields impact retail innovations, such as cross-industry collaborations. Encouraging interdisciplinary research could provide insights into how technologies from other fields are

influencing retail innovations, fostering cross-industry collaborations. By addressing these limitations, future research can provide a more nuanced understanding of the retail industry's technological landscape, offering valuable insights for businesses aiming to leverage technology for competitive advantage.

VI. CONCLUSION

In this research, we undertook a comprehensive exploration of the technological trends and collaboration networks within the retail industry by employing SNA and patent mining methodologies. Our study began with the collection of a substantial dataset, comprising 36,411 patents registered between 1995 and 2024, which was meticulously analyzed to uncover the intricate network of 8,225 entities engaged in 14,805 collaborative relationships. Through this extensive data collection and analysis, we were able to map out the complex web of interactions and collaborations that underpin innovation in the retail sector. By applying community detection algorithms, we identified 15 distinct technological domains that reflect the industry's focus areas, including Core Retail Operations, Digital Commerce, Retail Communication and Security Technologies, and Retail Product Display and Packaging Solutions, among others. The results of our analysis revealed that major industry players such as IBM, Target Brands Inc., and Procter & Gamble, occupy central positions in the network, highlighting their significant influence on technological advancements and collaborative efforts within the sector. Furthermore, the study provided valuable insights into the strategic concentration of innovation efforts within seven primary technology clusters, indicating a clear industry trend towards e-commerce, secure communication systems, and enhanced in-store experiences. These findings not only contribute to a deeper understanding of the technological evolution within the retail industry but also offer practical guidance for large corporations, SMEs, startups, and policymakers in navigating the rapidly evolving landscape of retail technology.

Q1. What is the structure and composition of the cooperation network involved in the registration of retail industry patents? The cooperation network of participants in the registration of retail industry patents reveals a highly interconnected web of entities and individuals actively collaborating to drive innovation in this sector. Comprising 8225 entities, the network is marked by 14805 collaborative relationships, indicating robust cooperation among members. This dense network facilitates the efficient exchange of ideas and resources, fostering a collaborative environment essential for the rapid advancement of retail technologies. The network's structure is characterized by several significant clusters, each representing key areas of innovation and development within the retail industry. These clusters, or communities, highlight the presence of influential groups that serve as hubs of collaboration, thereby accelerating the diffusion of technological advancements across the industry. The strategic positions of entities with high closeness and eigenvector centralities, such as Target Brands Inc and Check Point System Inc, underscore their roles as pivotal connectors and influencers within the network, capable of swiftly disseminating information and fostering extensive collaboration. Overall, the cooperation network exemplifies a dynamic and synergistic landscape that is instrumental in driving the evolution of retail industry patents. Our findings align closely with the analysis of Trappey et al. [29], which maps the economic impacts and technological expansions driven by smart retailing, illustrating similar interconnected patterns and influential clusters within the global patent landscape. However, contrary to the vibrant growth depicted here, Pantano et al. [120] report a deceleration in the rate of retail patent registrations, suggesting a potential saturation in technological innovations within the sector. This contrast highlights the nuanced dynamics of patent activities in retail, indicating regional and sectoral variances in innovation rates.

Q2. Who are the prominent figures and organizations in the retail industry patent network, and what roles do they fulfill? In the retail industry patent network, several key members stand out due to their influential roles and extensive collaborations. Among individuals, notable figures such as Jay S. Walker, James A. Jorasch, And Paul A. Moskowitz have made significant contributions, particularly in areas like retail innovation systems and AI for retail. Organizations like IBM, Target Brands Inc, Procter & Gamble, And Microsoft Corp are identified as central players, each specializing in different facets of retail technology. IBM's focus on AI and analytics, Target's emphasis on brand experience and operations, and Microsoft's advancements in digital retail platforms and voice technology highlight their pivotal roles. These entities not only contribute through their innovations but also serve as influential hubs within the network, fostering extensive collaborations that drive the overall growth and evolution of retail technologies. Their strategic positions enable them to effectively influence the network, making them indispensable to the continuous development and integration of new retail technologies. This mirrors findings by Kulkarni and Bansal [65], who noted the transformative potential of AI integrated by major entities such as Amazon and Alibaba in setting economic and technological trends in retail. Interestingly, the broader literature suggests a focus on incremental rather than radical innovations in retail, indicating that many entities might prioritize evolutionary development over disruptive technologies [120].

Q3. What are the primary technological domains represented by main participants in retail industry patents, and how do they contribute to the modernization and efficiency of the sector? The main technologies in retail industry patents encompass a diverse array of innovations, each contributing to the sector's modernization and efficiency. Key technology areas include Retail Product Display and Packaging Solutions, which focus on advancements in how products are presented and packaged to enhance consumer appeal and operational efficiency. Retail Communication and Security Technologies involve innovations in wireless

communication, signal transmission, and security protocols, crucial for safeguarding transactions and data. Core Retail Operations and Digital Commerce cover a wide range of technologies that facilitate online sales, customer interactions, and inventory management. Retail Technology Hardware and Infrastructure include developments in self-service kiosks, ATMs, and other physical systems that streamline retail operations. Specialized Retail Services and Consumer Goods focus on logistic and operational improvements, particularly in wearable goods and health-oriented products. Additionally, technologies in Retail Data Processing and Analysis, Retail Entertainment and Gaming Solutions, Retail Product Composition and Manufacturing, Retail RFID and Tracking Technologies, Retail Location and Proximity Services, Retail Data Privacy and Consent Management, and Specialized Food Retail represent significant advancements tailored to specific needs within the retail sector. These technologies collectively enhance various aspects of retail operations, from customer engagement and data security to product innovation and supply chain management. The spectrum of technologies we've identified parallels those explored by Trappey et al. [29], who noted the strategic deployment of smart retail technologies for enhancing operational efficiencies and consumer interactions across the sector

Q4. What trends are evident in the investment and concentration strategies of main actors across various technologies within the retail community? The investment trends within the retail sector highlight several strategic focuses that reflect a broader vision for the future of retail. Firstly, leading participants are channeling resources into strategic ecosystem development, building comprehensive digital ecosystems that include investments in scalable infrastructures like cloud computing. This technological advancement facilitates seamless integration of various retail processes, from inventory management to customer service, similar to the integration of AI in enhancing operational efficiency as noted by Kulkarni and Bansal [65]. Additionally, there is a significant push towards enhancing omnichannel capabilities, with investments in technologies that bridge online and offline retail experiences. This involves enhancing mobile platforms and developing omnichannel strategies to ensure a consistent customer experience across all touchpoints, reflecting a commitment to meeting consumers wherever they are, which aligns with observations that successful e-commerce platforms, such as Amazon and Alibaba, similar to the findings of Trappey et al. [29], significantly invest in smart technologies to blend digital and physical shopping realms. Moreover, retailers are increasingly prioritizing investment in sustainable and ethical technology. These investments focus on systems that optimize energy use within retail operations and innovations that support recycling and reducing waste in product packaging and logistics, a direction that is in line with prior research, and is crucial for maintaining competitiveness in the swiftly evolving retail landscape as AI-driven tools offer enhanced consumer engagement and innovative product and service offerings [65]. These trends are indicative of the retail industry's push towards not just modernizing capabilities but also aligning with consumer expectations for sustainability, ethical practices, and seamless shopping experiences across multiple platforms. This focus aims to secure a competitive edge in an evolving market and foster long-term consumer loyalty.

Future research should extend the exploration of technological trends and collaboration networks within the retail sector by specifically focusing on the intersection of artificial intelligence, cybersecurity, and e-commerce to understand their collective impact on strategic decision-making processes. Prospective studies could investigate how the evolving commitment to digital transformation and sustainability initiatives influences consumer behavior and market competition dynamics. Additionally, it is crucial to examine the effects of regulatory frameworks on patenting activities and collaborative interactions within the industry. Longitudinal analyses are recommended to monitor the progression of these technological domains over time, thereby offering a more nuanced understanding of the sector's adaptation to external pressures and its broader economic implications. This approach will provide valuable insights into the strategic alignments and innovations shaping the future of retail.

As the retail sector undergoes continued modernization and enhanced efficiency through technological advancements, it becomes increasingly imperative to understand and strategically leverage the insights derived from this network. Such comprehension and application are essential for fostering sustained growth and driving innovation within the industry.

REFERENCES

[1] T. Van Hung and V. T. N. Lien, "The antecedents and consequences of service recovery performance of frontline employees: A study of Vietnam retailing industry," *J. Eastern Eur. Central Asian Res. (JEECAR)*, vol. 8, no. 3, pp. 374–383, Sep. 2021, doi: 10.15549/jeecar.v8i3.667.

[2] A. Anika, "Examining the challenges and opportunities of talent acquisition and recruitment in urban retail stores," *Res. Square*, vol. 2024, pp. 1–30, Jan. 2024, doi: 10.21203/rs.3.rs-3818101/v1.

[3] O. Habiboglu, Ş. Özhan, and D. T. Akkaya, "A review of Turkish research on private label brand's," *Yönetim ve Ekonomi Araştrmalari Dergisi*, vol. 18, no. 1, pp. 218–232, Mar. 2020, doi: 10.11611/yead.574654.

[4] A. Podkalicka, "At home with gumtree: A cultural analysis of Australia's popular secondhand online marketplace," *Eur. J. Cultural Stud.*, vol. 25, no. 5, pp. 1410–1432, Oct. 2022, doi: 10.1177/13675494221079856.

[5] V. T. Dang, N. Nguyen, and J. Wang, "Consumers 'perceptions and responses towards online retailers' CSR," *Int. J. Retail Distrib. Manage.*, vol. 48, no. 12, pp. 1277–1299, Jul. 2020, doi: 10.1108/ijrdm-10-2019-0339.

[6] Y. Buana, "The role of word of Mouth's value co-creation on the achievement of sustainability," *Ganaya, Jurnal Ilmu Sosial dan Humaniora*, vol. 4, no. 2, pp. 846–866, Oct. 2021, doi: 10.37329/ganaya.v4i2.1428.

[7] A. Muditomo, Y. Syaukat, T. Andati, and N. Hasanah, "Payment system innovation and retailer efficiency: Measuring the impact of national payment gateway implementation in Indonesia," in *Proc. Bus. Innov. Eng. Conf. (BIEC)*, Jan. 2023, pp. 44–53, doi: 10.2991/978-94-6463-144-9_5.

[8] T. Guo and T. D. Palaoag, "Artificial intelligence driven e-commerce Business model under new retail environment," in *Proc. 2nd Int. Conf. Inf., Control Automat., (ICICA)*, 2023, pp. 1–14, doi: 10.4108/eai.2-12-2022.2328056.

[9] E. Timotius, O. Sunardi, I. A. Soenandi, M. Ginting, and B. Sabini, "Supply chain disruption in time of crisis: A case of the Indonesian retail sector," *J. Int. Logistics Trade*, vol. 20, no. 2, pp. 78–101, Sep. 2022, doi: 10.1108/jilt-05-2022-0004.

[10] S. Surahman, A. B. Mardhanie, T. R. Hutauruk, D. Harits, and M. Salmani, "Utilization of supply chain and benefit-cost analysis to determining warehousing area in penajam paser utara regency," in *Proc. Int. Conf. Appl. Sci. Technol. Social Sci. (iCAST-SS)*, 2022, pp. 621–627, doi: 10.2991/assehr.k.220301.102.

[11] R. Woods, O. Doherty, and S. Stephens, "Technology driven change in the retail sector: Implications for higher education," *Ind. Higher Edu.*, vol. 36, no. 2, pp. 128–137, Apr. 2022, doi: 10.1177/09504222211009180.

[12] Q. Wang and N. Zheng, "Research on artificial intelligence technology empowering new retail: A case study of unmanned retail," in *Proc. 2nd Int. Academic Conf. Blockchain, Inf. Technol. Smart Finance (ICBIS)*, Jan. 2023, pp. 1135–1145, doi: 10.2991/978-94-6463-198-2_117.

[13] Y. Zhan, R. Han, M. Tse, M. H. Ali, and J. Hu, "A social media analytic framework for improving operations and service management: A study of the retail pharmacy industry," *Technol. Forecasting Social Change*, vol. 163, Feb. 2021, Art. no. 120504.

[14] R. Pillarisetty and P. Mishra, "A review of AI (artificial intelligence) tools and customer experience in online fashion retail," *Int. J. E-Bus. Res.*, vol. 18, no. 2, pp. 1–12, Jan. 2022.

[15] A. F. D. Carpio, "Analyzing computer vision models for detecting customers: A practical experience in a Mexican retail," *Int. J. Adv. Intell. Inf.*, vol. 10, no. 1, p. 131, Feb. 2024.

[16] D. G. Chand, "Transformation of retail sector: A critical review of Indian retailers," *Int. J. Res. Marketing Manage. Sales*, vol. 4, no. 2, pp. 51–55, Jul. 2022, doi: 10.33545/26633329.2022.v4.i2a.153.

[17] B. Burgess, G. Yaoyuneyong, W. A. Pollitte, and P. Sullivan, "Adopting retail technology in crises: Integrating TAM and prospect theory perspectives," *Int. J. Retail Distrib. Manage.*, vol. 51, no. 7, pp. 939–954, Jul. 2023, doi: 10.1108/ijrdm-05-2022-0153.

[18] B. B. Gupta, A. Gaurav, and P. K. Panigrahi, "Analysis of retail sector research evolution and trends during COVID-19," *Technol. Forecasting Social Change*, vol. 194, Jun. 2023, Art. no. 122671.

[19] S. Ozcan, A. Homayounfard, C. Simms, and J. Wasim, "Technology roadmapping using text mining: A foresight study for the retail industry," *IEEE Trans. Eng. Manag.*, vol. 69, no. 1, pp. 228–244, Feb. 2022, doi: 10.1109/TEM.2021.3068310.

[20] F. Almaslamani, R. Abuhussein, H. Saleet, L. AbuHilal, and N. Santarisi, "Using big data analytics to design an intelligent market basket-case study at sameh mall," *Int. J. Eng. Res. Technol.*, vol. 13, no. 11, p. 3444, Nov. 2020, doi: 10.37624/ijert/13.11.2020.3444-3455.

[21] M. Cooper, "Exploring technology adoption trends among entrepreneurial start-ups on the digital frontier," *Res. Square*, vol. 2024, pp. 1–12, Mar. 2024, doi: 10.21203/rs.3.rs-4094787/v1.

[22] M. Vido, G. Scur, A. A. Massote, and F. Lima, "The impact of the collaborative robot on competitive priorities: Case study of an automotive supplier," *Gestão Produção*, vol. 27, no. 4, pp. 1–21, 2020, doi: 10.1590/0104-530x5358-20.

[23] W. Klongthong, V. Muangsin, C. Gowanit, and N. Muangsin, "A patent analysis to identify emergent topics and convergence fields: A case study of chitosan," *Sustainability*, vol. 13, no. 16, p. 9077, Aug. 2021, doi: 10.3390/su13169077.

[24] Y. Tian, "Development overview of electric vehicle industry based on patent data analysis," *Proc. SPIE*, vol. 12510, pp. 192–197, Jan. 2023, doi: 10.1117/12.2656790.

[25] B. Bai and G. Wu, "The role of big data in the formation of supply chain platform for new forms of online retail," *Chin. Manage. Stud.*, vol. 18, no. 4, pp. 1047–1064, Jun. 2024.

[26] L. L. O. Ocaña, D. P. Ruiz, and B. V. Fiallos, "Optimizing retail business strategies with advanced analytics and improved business intelligence techniques," *J. Intell. Syst. Internet Things*, vol. 11, no. 1, pp. 75–83, 2024.

[27] A. J. C. Trappey, C. V. Trappey, A.-C. Chang, and J. X. K. Li, "Deriving competitive foresight using an ontology-based patent roadmap and valuation analysis," *Int. J. Semantic Web Inf. Syst.*, vol. 15, no. 2, pp. 68–91, Apr. 2019.

[28] E. P. Mondol, "The impact of block chain and smart inventory system on supply chain performance at retail industry," *Int. J. Comput., Inf. Manuf. (IJCIM)*, vol. 1, no. 1, pp. 1–21, Dec. 2021, doi: 10.54489/ijcim.v1i1.30.

[29] A. J. C. Trappey, C. Trappey, W. C. Wang, and H. I. Hsieh, "Patent analysis of key technologies for smart retailing and their projected economic impact," in *Proc. IEEE 22nd Int. Conf. Comput. Supported Cooperat. Work Design ((CSCWD))*, May 2018, pp. 582–587.

[30] H.-P. Lu, H.-L. Cheng, J.-C. Tzou, and C.-S. Chen, "Technology roadmap of AI applications in the retail industry," *Technol. Forecasting Social Change*, vol. 195, Oct. 2023, Art. no. 122778, doi: 10.1016/j.techfore.2023.122778.

[31] K. Ali, A. X. Liu, E. Chai, and K. Sundaresan, "Monitoring browsing behavior of customers in retail stores via RFID imaging," *IEEE Trans. Mobile Comput.*, vol. 21, no. 3, pp. 1034–1048, Mar. 2022.

[32] M. Morenza-Cinos, V. Casamayor-Pujol, and R. Pous, "Stock visibility for retail using an RFID robot," *Int. J. Phys. Distrib. Logistics Manage.*, vol. 49, no. 10, pp. 1020–1042, Dec. 2019, doi: 10.1108/ijpdlm-03-2018-0151.

[33] M. Qi, H. Mak, and Z. M. Shen, "Data-driven research in retail operations—A review," *Nav. Res. Logistics (NRL)*, vol. 67, no. 8, pp. 595–616, Oct. 2020.

[34] M. G. Dekimpe, "Retailing and retailing research in the age of big data analytics," *Int. J. Res. Marketing*, vol. 37, no. 1, pp. 3–14, Mar. 2020.

[35] G. Santoro, F. Fiano, B. Bertoldi, and F. Ciampi, "Big data for business management in the retail industry," *Manage. Decis.*, vol. 57, no. 8, pp. 1980–1992, Sep. 2019.

[36] E. Pantano and V. Vannucci, "Who is innovating? An exploratory research of digital technologies diffusion in retail industry," *J. Retailing Consum. Services*, vol. 49, pp. 297–304, Jul. 2019.

[37] R. I. Mustikowati, E. Sarwoko, M. Arief, and I. N. Nurfarida, "Marketing investigation: Customer relationship management and innovation to improve competitive advantage and business performance," *Humanities Social Sci. Lett.*, vol. 9, no. 4, pp. 430–438, Dec. 2021, doi: 10.18488/journal.73.2021.94.430.438.

[38] V. Shankar, K. Kalyanam, P. Setia, A. Golmohammadi, S. Tirunillai, T. Douglass, J. Hennessey, J. S. Bull, and R. Waddoups, "How technology is changing retail," *J. Retailing*, vol. 97, no. 1, pp. 13–27, Mar. 2021.

[39] N. Ivanova, "The future of retail: Innovations and basic trends," in *Economic Systems in the New Era: Stable Systems in an Unstable World*. Cham, Switzerland: Springer, 2021, pp. 157–163.

[40] H. Zhou, J. Dai, X. Chen, B. Hu, H. Wei, and H. H. Cai, "Understanding innovation of new energy industry: Observing development trend and evolution of hydrogen fuel cell based on patent mining," *Int. J. Hydrogen Energy*, vol. 52, pp. 548–560, Jan. 2024.

[41] Z. Liu, Y. Zhang, W. Deng, J. Ma, and X. Fan, "A deep learning method for recommending university patents to industrial clusters by common technological needs mining," *Scientometrics*, vol. 129, no. 6, pp. 3089–3113, Jun. 2024.

[42] U. Fatima, S. Hina, and M. Wasif, "A novel global clustering coefficient-dependent degree centrality (GCCDC) metric for large network analysis using real-world datasets," *J. Comput. Sci.*, vol. 70, Jun. 2023, Art. no. 102008.

[43] A. Moiz, U. Fatima, and M. Z. U. Haque, "A new framework for pinpointing crucial proteins in protein-protein interaction networks," *IEEE Access*, vol. 12, pp. 108425–108444, 2024.

[44] M. A. Khashan, M. M. Elsotouhy, T. H. Alasker, and M. A. Ghonim, "Investigating retailing customers' adoption of augmented reality apps: Integrating the unified theory of acceptance and use of technology (UTAUT2) and task-technology fit (TTF)," *Marketing Intell. Planning*, vol. 41, no. 5, pp. 613–629, Jul. 2023.

[45] N. A. Channa, M. H. Bhutto, M. Bhutto, N. A. Bhutto, and B. Tariq, "Capturing customer's store loyalty through relationship benefits: Moderating effect of retail innovation," *Eur. Bus. Rev.*, vol. 34, no. 1, pp. 20–40, Jan. 2022, doi: 10.1108/ebr-09-2019-0179.

[46] M. Bălăşescu, "Innovation in retail," *Ser. V-Econ. Sci.*, vol. 14, no. 2, pp. 129–134, Dec. 2021, doi: 10.31926/but.es.2021.14.63.2.15.

[47] R. Bruni and M. Piccarozzi, "Industry 4.0 enablers in retailing: A literature review," *Int. J. Retail Distribution Manage.*, vol. 50, no. 7, pp. 816–838, Jun. 2022, doi: 10.1108/ijrdm-07-2021-0314.

[48] X. Li and T. Wang, "The moderating role of supply chain relationships in digital transformation and innovation performance-multiple linear regression analysis," in *Proc. 5th Int. Conf. Econ. Manage. Model Eng. (ICEMME)*, Beijing, China, 2024, pp. 1–8, doi: 10.4108/eai.17-11-2023.2342689.

[49] D. D. S. Luamba, D. M. L. J. Blye, D. I. A. Williams, and J. Chagadama, "Innovative strategies for small retail companies' sustainability," *Int. J. Bus. Manage. Res.*, vol. 9, no. 3, pp. 330–338, Sep. 2021, doi: 10.37391/ijbmr.090311.

[50] N. Nurjanah, "Coffee shop new retail business model," *Int. J. Entrepreneurship, Bus. Creative Economy*, vol. 2, no. 2, pp. 1–7, Jul. 2022, doi: 10.31098/ijebce.v2i2.786.
[51] H. Evanschitzky, B. Bartikowski, T. Baines, M. Blut, C. Brock, K. Kleinlercher, P. Naik, O. Petit, T. Rudolph, C. Spence, C. Velasco, and N. V. Wünderlich, "Digital disruption in retailing and beyond," *J. Service Manage. Res.*, vol. 4, no. 4, pp. 187–204, 2020, doi: 10.15358/2511-8676-2020-4-187.
[52] G. Cakir, R. Iftikhar, A. Bielozorov, Z. Pourzolfaghar, and M. Helfert, "Omnichannel retailing: Digital transformation of a medium-sized retailer," *J. Inf. Technol. Teach. Cases*, vol. 11, no. 2, pp. 122–126, Nov. 2021, doi: 10.1177/2043886920959803.
[53] A. Butt, H. Ahmad, F. Ali, A. Muzaffar, and M. N. Shafique, "Engaging the customer with augmented reality and employee services to enhance equity and loyalty," *Int. J. Retail Distrib. Manage.*, vol. 51, no. 5, pp. 629–652, Apr. 2023, doi: 10.1108/ijrdm-04-2021-0165.
[54] H. Alboqami, "Factors affecting consumers adoption of AI-based chatbots: The role of anthropomorphism," *Amer. J. Ind. Bus. Manage.*, vol. 13, no. 4, pp. 195–214, 2023, doi: 10.4236/ajibm.2023.134014.
[55] C. Gil-López, J. Guixeres, J. Marín-Morales, C. Torrecilla, E. Williams, and M. Alcañiz, "Is mixed reality technology an effective tool for retail? A vividness and interaction perspective," *Frontiers Virtual Reality*, vol. 4, Apr. 2023, Art. no. 1067932, doi: 10.3389/frvir.2023.1067932.
[56] N. Al-Nabet, "A case study of the benefits of the IoT in the Qatari retail industry," *Stud. Bus. Econ.*, vol. 24, no. 1, pp. 86–107, 2021, doi: 10.29117/sbe.2021.0128.
[57] M. Roe, K. Spanaki, A. Ioannou, E. D. Zamani, and M. Giannakis, "Drivers and challenges of Internet of Things diffusion in smart stores: A field exploration," *Technol. Forecasting Social Change*, vol. 178, Mar. 2022, Art. no. 121593.
[58] E. Purwaningsih, M. Muslikh, S. Suhaeri, and B. Basrowi, "Utilizing blockchain technology in enhancing supply chain efficiency and export performance, and its implications on the financial performance of SMEs," *Uncertain Supply Chain Manage.*, vol. 12, no. 1, pp. 449–460, 2024.
[59] F. Bonetti, G. Warnaby, and L. Quinn, "Augmented reality and virtual reality in physical and online retailing: A review, synthesis and research Agenda," in *Augmented Reality and Virtual Reality*, 2017, pp. 119–132, doi: 10.1007/978-3-319-64027-3_9.
[60] V. Lavoye, J. Mero, and A. Tarkiainen, "Consumer behavior with augmented reality in retail: A review and research agenda," *Int. Rev. Retail, Distrib. Consum. Res.*, vol. 31, no. 3, pp. 299–329, May 2021, doi: 10.1080/09593969.2021.1901765.
[61] R. Liu, B. Balakrishnan, and E. M. Saari, "How AR technology is changing consumer shopping habits: From traditional retail to virtual fitting," *Academic J. Sci. Technol.*, vol. 9, no. 2, pp. 140–144, Feb. 2024, doi: 10.54097/n5fk7m44.
[62] R. Pozharliev, M. D. Angelis, and D. Rossi, "The effect of augmented reality versus traditional advertising: A comparison between neurophysiological and self-reported measures," *Marketing Lett.*, vol. 33, no. 1, pp. 113–128, Mar. 2022, doi: 10.1007/s11002-021-09573-9.
[63] P. S. Dhoni, "From data to decisions: Enhancing retail with AI and machine learning," *Int. J. Comput. Eng.*, vol. 5, no. 1, pp. 38–51, Feb. 2024, doi: 10.47941/ijce.1660.
[64] H.-P. Fu, T.-H. Chang, S.-W. Lin, Y.-H. Teng, and Y.-Z. Huang, "Evaluation and adoption of artificial intelligence in the retail industry," *Int. J. Retail Distrib. Manage.*, vol. 51, no. 6, pp. 773–790, May 2023, doi: 10.1108/ijrdm-12-2021-0610.
[65] N. D. Kulkarni and S. Bansal, "Exploring real-world applications of GenAI in retail," *J. Artif. Intell. Cloud Comput.*, vol. 2023, pp. 1–5, Dec. 2023, doi: 10.47363/jaicc/2023(2)186.
[66] A. B. Mahmoud, S. Tehseen, and L. Fuxman, "The dark side of artificial intelligence in retail innovation," in *Retail Futures*, E. Pantano, Ed. Emerald Publishing Limited, 2020, pp. 165–180, doi: 10.1108/978-1-83867-663-620201019.
[67] Z. Wang, "The influence of artificial intelligence on retail marketing," *Adv. Econ., Manage. Political Sci.*, vol. 71, no. 1, pp. 106–111, Jan. 2024, doi: 10.54254/2754-1169/71/20241443.
[68] S. R. Hamidi, M. A. M. Yusof, S. M. Shuhidan, and S. A. Kadir, "IR4.0: Unmanned store apps," *Indonesian J. Electr. Eng. Comput. Sci.*, vol. 17, no. 3, p. 1540, Mar. 2020, doi: 10.11591/ijeecs.v17.i3.pp1540-1547.
[69] M. Kahlert, E. Constantinides, and S. A. D. Vries, "The relevance of technological autonomy in the customer acceptance of IoT services in retail," in *Proc. ICC*, 2017, pp. 1–12, doi: 10.1145/3018896.3018906.
[70] K. S. Karthikeyan and T. Nagaprakash, "Prioritizing IoT-driven sustainability initiatives in retail chains: Exploring case studies and industry insights," *EAI Endorsed Trans. Internet Things*, vol. 10, pp. 1–12, Dec. 2023, doi: 10.4108/eetiot.4628.
[71] Y. Liu, Z. Ni, M. Karlsson, and S. Gong, "Methodology for digital transformation with Internet of Things and cloud computing: A practical guideline for innovation in Small- and medium-sized enterprises," *Sensors*, vol. 21, no. 16, p. 5355, Aug. 2021, doi: 10.3390/s21165355.
[72] T. de Vass, H. Shee, and S. Miah, "IoT in supply chain management: Opportunities and challenges for businesses in early industry 4.0 context," *Oper. Supply Chain Manage., Int. J.*, vol. 2021, pp. 148–161, Jan. 2021, doi: 10.31387/oscm0450293.
[73] P. K. Donepudi, "Robots in retail marketing: A timely opportunity," *Global Discl. Econ. Bus.*, vol. 9, no. 2, pp. 97–106, Nov. 2020, doi: 10.18034/gdeb.v9i2.527.
[74] A. Galdelli, R. Pietrini, A. Mancini, and P. Zingaretti, "Retail robot navigation: A shopper behavior-centric approach to path planning," *IEEE Access*, vol. 12, pp. 50154–50164, 2024, doi: 10.1109/ACCESS.2024.3384360.
[75] J. C. F. L. Guido, J. W. Kim, P. T. L. P. Leszczyc, N. Pontes, and S. Tuzovic, "Retail robots as sales assistants: How speciesism moderates the effect of robot intelligence on customer perceptions and behaviour," *J. Service Theory Pract.*, vol. 34, no. 1, pp. 127–154, Jan. 2024, doi: 10.1108/jstp-04-2023-0123.
[76] K. Willems, N. Verhulst, L. D. Gauquier, and M. Brengman, "Frontline employee expectations on working with physical robots in retailing," *J. Service Manage.*, vol. 34, no. 3, pp. 467–492, Apr. 2023, doi: 10.1108/josm-09-2020-0340.
[77] G. Rancati and I. Maggioni, "Neurophysiological responses to robot–human interactions in retail stores," *J. Services Marketing*, vol. 37, no. 3, pp. 261–275, Feb. 2023, doi: 10.1108/jsm-04-2021-0126.
[78] O. Okuyelu, O. O. Adaji, and B. Doskenov, "Advancing manufacturing efficiency through real-time production monitoring and control systems," *J. Eng. Res. Rep.*, vol. 26, no. 4, pp. 184–193, Mar. 2024, doi: 10.9734/jerr/2024/v26i41125.
[79] T. Yamashiro, Y. Honma, R. Togo, T. Ogawa, and M. Haseyama, "Customer interest estimation method in real store using re-identification and 3D posture estimation models," in *Proc. Int. Workshop Adv. Imag. Technol. (IWAIT)*, Mar. 2023, p. 48, doi: 10.1117/12.2666862.
[80] M. A. Zurkanain and S. K. Subramaniam, "Investigation and implementation of IoT based oil & gas pipeline monitoring system," *Int. J. Recent Technol. Appl. Sci. (IJORTAS)*, vol. 5, no. 1, pp. 1–11, Mar. 2023, doi: 10.36079/lamintang.ijortas-0501.477.
[81] R. Liu, B. Balakrishnan, and E. M. Saari, "The impact of augmented reality (AR) technology on Consumers' purchasing decision processes," *Frontiers Bus., Econ. Manage.*, vol. 13, no. 2, pp. 181–185, Feb. 2024, doi: 10.54097/1r7f1x56.
[82] M. Wang, "The impact of virtual reality on the customer experience in the luxury industry," *BCP Bus. Manage.*, vol. 42, pp. 197–204, Mar. 2023, doi: 10.54691/bcpbm.v42i.4582.
[83] S. Alacam and A. Sencer, "Using blockchain technology to foster collaboration among shippers and carriers in the trucking industry: A design science research approach," *Logistics*, vol. 5, no. 2, p. 37, Jun. 2021, doi: 10.3390/logistics5020037.
[84] M. A. Alqarni, M. S. Alkatheiri, S. H. Chauhdary, and S. Saleem, "Use of blockchain-based smart contracts in logistics and supply chains," *Electronics*, vol. 12, no. 6, p. 1340, Mar. 2023, doi: 10.3390/electronics12061340.
[85] M. S. Faridi, S. Ali, G. Wang, S. A. Awan, and M. Z. Iqbal, "ChainApparel: A trustworthy blockchain and IoT-based traceability framework for apparel industry 4.0," *Comput., Mater. Continua*, vol. 77, no. 2, pp. 1837–1854, 2023, doi: 10.32604/cmc.2023.041929.
[86] N. Liu, J. Lin, S. Guo, and X. Shi, "Fashion platform operations in the sharing economy with digital technologies: Recent development and real case studies," *Ann. Oper. Res.*, vol. 329, nos. 1–2, pp. 1175–1195, Oct. 2023, doi: 10.1007/s10479-022-04544-3.
[87] X. Ma and D. Dai, "Certifying greenness: Blockchain's impact on eco-friendly products in a competitive market," *IEEE Access*, vol. 12, pp. 782–793, 2024, doi: 10.1109/ACCESS.2023.3347743.
[88] M. Rogerson and G. C. Parry, "Blockchain: Case studies in food supply chain visibility," *Supply Chain Manage., Int. J.*, vol. 25, no. 5, pp. 601–614, May 2020, doi: 10.1108/scm-08-2019-0300.

[89] J.-S. Chen, T.-T.-Y. Le, and D. Florence, "Usability and responsiveness of artificial intelligence chatbot on online customer experience in e-retailing," *Int. J. Retail Distrib. Manage.*, vol. 49, no. 11, pp. 1512–1531, Oct. 2021, doi: 10.1108/ijrdm-08-2020-0312.

[90] H. Margono, D. Bastian, and N. A. Faiza, "Narrative literature review: Efficiency enhancement–user trust in chatbots as a tool for improving service quality by humans," *J. Soft Comput. Explor.*, vol. 5, no. 2, pp. 107–114, May 2024, doi: 10.52465/joscex.v5i2.286.

[91] J. Rana, R. Jain, and V. Nehra, "Utility and acceptability of AI-enabled chatbots on the online customer journey in e-retailing," *Int. J. Comput. Digit. Syst.*, vol. 15, no. 1, pp. 323–335, Jan. 2024, doi: 10.12785/ijcds/150125.

[92] A. Ranieri, I. D. Bernardo, and C. Mele, "Serving customers through chatbots: Positive and negative effects on customer experience," *J. Service Theory Pract.*, vol. 34, no. 2, pp. 191–215, Mar. 2024, doi: 10.1108/jstp-01-2023-0015.

[93] A. D. Vergaray, W. F. P. Robles, and J. A. S. Jiménez, "The impact of chatbots on customer satisfaction: A systematic literature review," *TEM J.*, vol. 12, no. 3, pp. 1407–1417, 2023.

[94] I. Oncioiu, "Predicting the use of chatbots for consumer channel selection in multichannel environments: An exploratory study," *Systems*, vol. 11, no. 10, p. 522, Oct. 2023, doi: 10.3390/systems11100522.

[95] V. Marios, "Revolutionizing supermarket checkout: A comprehensive review of radio frequency identification (RFID)-enabled shopping carts for automatic payments and real-time inventory tracking," *Trends Comput. Sci. Inf. Technol.*, vol. 9, no. 1, pp. 52–55, Apr. 2024, doi: 10.17352/tcsit.000080.

[96] G. Alfian, M. Q. H. Octava, F. M. Hilmy, R. A. Nurhaliza, Y. M. Saputra, D. G. P. Putri, F. Syahrian, N. L. Fitriyani, F. T. D. Atmaji, U. Farooq, D. T. Nguyen, and M. Syafrudin, "Customer shopping behavior analysis using RFID and machine learning models," *Information*, vol. 14, no. 10, p. 551, Oct. 2023, doi: 10.3390/info14100551.

[97] S. Purohit and A. K. Jain, "RFID: The silver bullet towards seamless Indian petro retail customer service," *Indian J. Sci. Technol.*, vol. 15, no. 43, pp. 2290–2296, Nov. 2022, doi: 10.17485/ijst/v15i43.1773.

[98] G. Khalil, R. Doss, and M. Chowdhury, "A new secure RFID anti-counterfeiting and anti-theft scheme for merchandise," *J. Sensor Actuator Netw.*, vol. 9, no. 1, p. 16, Mar. 2020, doi: 10.3390/jsan9010016.

[99] M. Giannakis, K. Spanaki, and R. Dubey, "A cloud-based supply chain management system: Effects on supply chain responsiveness," *J. Enterprise Inf. Manage.*, vol. 32, no. 4, pp. 585–607, Jul. 2019, doi: 10.1108/jeim-05-2018-0106.

[100] A. E. Oke, A. F. Kineber, I. Al-Bukhari, I. Famakin, and C. Kingsley, "Exploring the benefits of cloud computing for sustainable construction in Nigeria," *J. Eng., Des. Technol.*, vol. 21, no. 4, pp. 973–990, Jul. 2023, doi: 10.1108/jedt-04-2021-0189.

[101] N. Settia, "Unleashing the potential: Compliance standards using cloud computing," *Int. Res. J. Adv. Eng. Hub*, vol. 2, no. 3, pp. 641–644, 2024, doi: 10.47392/irjaeh.2024.0092.

[102] A. Nigar, S. Saeed, and S. N. Hussaieni, "Key opportunities and challenges of migrating IT resources to cloud computing," *Trends Tech. Sci. Res.*, vol. 6, no. 1, pp. 1–8, Mar. 2023, doi: 10.19080/ttsr.2023.06.555680.

[103] S. K. Roy, M. S. Balaji, A. Quazi, and M. Quaddus, "Predictors of customer acceptance of and resistance to smart technologies in the retail sector," *J. Retailing Consum. Services*, vol. 42, pp. 147–160, May 2018, doi: 10.1016/j.jretconser.2018.02.005.

[104] A. R. Pereira, "The influence of cognitive technologies on the decision-making process and the purchasing experience in retail," *Manage.*, vol. 29, no. 1, pp. 113–129, 2024, doi: 10.30924/mjcmi.29.1.8.

[105] S. W. Ali, T. A. Wani, and N. Tyagi, "A qualitative study on innovation and dimensional aspects of the omnichannel retail business model," *Int. J. E-Bus. Res.*, vol. 18, no. 2, pp. 1–20, Jan. 2022, doi: 10.4018/ijebr.294108.

[106] P. U. Uwaoma, E. O. Eboigbe, N. L. Eyo-Udo, A. C. Ijiga, S. Kaggwa, and A. I. Daraojimba, "Mixed reality in U.S. retail: A review: Analyzing the immersive shopping experiences, customer engagement, and potential economic implications," *World J. Adv. Res. Rev.*, vol. 20, no. 3, pp. 966–981, Dec. 2023, doi: 10.30574/wjarr.2023.20.3.2495.

[107] Q. Shang, "Core patent mining in edge computing based on innovation citation," *Proc. SPIE*, vol. 12250, pp. 255–260, May 2022.

[108] Y. G. Hernández and J. F. R. Galvis, "Innovation and patents as a business success factor," *J. Econ., Finance Administ. Sci.*, vol. 26, no. 51, pp. 143–159, Jul. 2021.

[109] S. Sarica, B. Yan, and J. Luo, "Data-driven intelligence on innovation and competition: Patent overlay network visualization and analytics," *Inf. Syst. Manage.*, vol. 37, no. 3, pp. 198–212, Jul. 2020.

[110] L. Ponta, G. Puliga, L. Oneto, and R. Manzini, "Identifying the determinants of innovation capability with machine learning and patents," *IEEE Trans. Eng. Manag.*, vol. 69, no. 5, pp. 2144–2154, Oct. 2022.

[111] C. Chen and H. Zhang, "Analyzing knowledge innovation mechanism using patent data mining and network construction," in *Proc. 4th Int. Conf. Big Data Technol.*, Sep. 2021, pp. 128–133.

[112] A. Daly, G. Valacchi, and J. D. Raffo, "Mining patent data: Measuring innovation in the mining industry with patents," *World Intellectual Property Org. (WIPO) Econ. Res. Work. Paper Ser.*, vol. 2019, no. 56, pp. 1–62, May 2019.

[113] L. Sandrini, "Innovation, competition, and incomplete adoption of a superior technology," *Econ. Innov. New Technol.*, vol. 32, no. 6, pp. 783–803, Aug. 2023.

[114] E. Alessandri, "Identifying technological trajectories in the mining sector using patent citation networks," *Resour. Policy*, vol. 80, Jan. 2023, Art. no. 103130.

[115] Y. Li, Y. Rong, U. M. Ahmad, X. Wang, J. Zuo, and G. Mao, "A comprehensive review on green buildings research: Bibliometric analysis during 1998–2018," *Environ. Sci. Pollut. Res.*, vol. 28, no. 34, pp. 46196–46214, Sep. 2021, doi: 10.1007/s11356-021-12739-7.

[116] J. Hwang, K. H. Kim, J. G. Hwang, S. Jun, J. Yu, and C. Lee, "Technological opportunity analysis: Assistive technology for blind and visually impaired people," *Sustainability*, vol. 12, no. 20, p. 8689, Oct. 2020, doi: 10.3390/su12208689.

[117] C. C. Guderian, P. M. Bican, F. J. Riar, and S. Chattopadhyay, "Innovation management in crisis: Patent analytics as a response to the COVID-19 pandemic," *R D Manage.*, vol. 51, no. 2, pp. 223–239, Mar. 2021, doi: 10.1111/radm.12447.

[118] S. Jun, "Technology integration and analysis using boosting and ensemble," *J. Open Innov., Technol., Market, Complex.*, vol. 7, no. 1, p. 27, Mar. 2021, doi: 10.3390/joitmc7010027.

[119] C.-Y. Huang, J.-J. Huang, Y.-N. Chang, and Y.-C. Lin, "A fuzzy-MOP-based competence set expansion method for technology roadmap definitions," *Mathematics*, vol. 9, no. 2, p. 135, Jan. 2021, doi: 10.3390/math9020135.

[120] E. Pantano, C.-V. Priporas, and N. Stylos, "Knowledge push curve (KPC) in retailing: Evidence from patented innovations analysis affecting retailers' competitiveness," *J. Retailing Consum. Services*, vol. 44, pp. 150–160, Sep. 2018.

[121] J. Tan, Y. Wang, and J. Chu, "A consensus method in social network large-scale group decision making with interval information," *Expert Syst. Appl.*, vol. 237, Mar. 2024, Art. no. 121560.

[122] M. Kostic and D. Draskovic, "Complex network analysis of Women's singles tennis matches," in *Proc. 28th Telecommun. Forum (TELFOR)*, Nov. 2020, pp. 1–4.

[123] M. Jacomy and A. K. Munk, "Interfering with the black-box-tradeoff model: Gephisto, a one-click gephi for critical technical practice," *Converg., Int. J. Res. New Media Technol.*, vol. 30, no. 1, pp. 142–166, Feb. 2024.

[124] K. Cherven, *Mastering Gephi Network Visualization*. Birmingham, U.K.: Packt Publishing, 2015.

[125] M. C. S. Irawan, A. Purnomo, A. N. Sanjaya, Meiryani, S. Ubud, and F. I. Maulana, "Global patent landscape of decision support system in the business: An overview," in *Proc. Int. Conf. Inf. Manage. Technol. (ICIMTech)*, Aug. 2023, pp. 464–469.

[126] M. Maskittou, A. E. Haddadi, and H. Routaib, "Feature learning of patent networks using tensor decomposition," in *Proc. 5th Int. Conf. Smart City Appl.*, vol. 4. Cham, Switzerland: Springer, 2021, pp. 1375–1390.

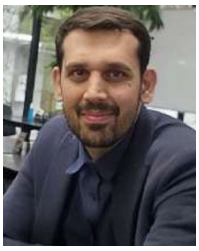
[127] J. Lu and Y.-W. Si, "Clustering-based force-directed algorithms for 3D graph visualization," *J. Supercomput.*, vol. 76, no. 12, pp. 9654–9715, Dec. 2020.

[128] M. E. J. Newman, "Modularity and community structure in networks," *Proc. Nat. Acad. Sci.*, vol. 103, no. 23, pp. 8577–8582, Jun. 2006.

[129] M. Yap, D. Luo, O. Cats, N. van Oort, and S. Hoogendoorn, "Where shall we sync? Clustering passenger flows to identify urban public transport hubs and their key synchronization priorities," *Transp. Res. C, Emerg. Technol.*, vol. 98, pp. 433–448, Jan. 2019.

[130] J. Zhu, B. Chen, and Y. Zeng, "Community detection based on modularity and k-plexes," *Inf. Sci.*, vol. 513, pp. 127–142, Mar. 2020.
[131] S. Chattopadhyay, T. Basu, A. K. Das, K. Ghosh, and L. C. A. Murthy, "Towards effective discovery of natural communities in complex networks and implications in e-commerce," *Electron. Commerce Res.*, vol. 21, no. 4, pp. 917–954, Dec. 2021.

NAVID MOHAMMADI received the Master of Science degree in management of technology, with a focus on innovation management and the Ph.D. degree in entrepreneurship management, specializing in new ventures from the University of Tehran. He is currently an Assistant Professor with the Faculty of Commerce and Trade, University of Tehran. His academic expertise encompasses entrepreneurship, innovation ecosystems, and new venture development. In addition to his academic role, he is an experienced business developer and a startup mentor, collaborating with emerging businesses to foster growth and innovation. His work bridges academic research and practical business applications, making significant contributions to the entrepreneurial ecosystem through both teaching and mentorship.



MEHRDAD MAGHSOUDI received the master's degree in industrial management from Allameh Tabataba'i University. He is currently pursuing the Ph.D. degree in information technology management with Shahid Beheshti University, Tehran, specializing in business intelligence. His expertise spans a range of advanced techniques, including patent analysis, social network analysis, text mining, and process mining. He has applied these skills in various research projects, showcasing his ability to integrate complex data analysis methodologies. In addition to his academic work, he is a consultant on data-driven projects, leveraging his knowledge to provide insights and solutions in applied data science and business intelligence.

MAHDI SOGHI is currently pursuing the master's degree in international business with the Faculty of Commerce and Trade, University of Tehran. His academic focus includes global business strategies, international trade, and cross-cultural management. He is also a Teaching Assistant with the University of Tehran, where he contributes to undergraduate courses in business and management, supporting the academic development of students.