“Mapping research trends in online shopping behavior during the fourth industrial revolution: A bibliometric analysis”

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MAPPING RESEARCH TRENDS IN ONLINE SHOPPING BEHAVIOR DURING THE FOURTH INDUSTRIAL REVOLUTION: A BIBLIOMETRIC ANALYSIS

Abstract

Online shopping behavior has been profoundly reshaped by the technological acceleration of the Fourth Industrial Revolution (IR 4.0), making it essential to understand how artificial intelligence and digital integration influence consumer decision-making. The study aims to map and quantify emerging trends in online consumer behavior research from 2019 to 2025. A bibliometric analysis was conducted on 485 Scopus-indexed articles using Python packages, incorporating keyword co-occurrence, thematic evolution, Kleinberg's burst detection, and N-gram with Document-Term Matrix (DTM) analyses. The results reveal five dominant clusters: Consumer Behavior & Smart Retail, Intelligent Commerce, Data-Driven Behavior, Smart Experience, and Neuro-Behavioral Analytics that collectively define the field's intellectual structure. Publication output grew dynamically, rising 19.6% in 2020, 10.9% in 2021, and peaking at 37.7% in 2022, before regaining momentum with a 29.6% increase in 2024, with an average of 19.8 citations per document. The mean burst strength (94.6%) indicates accelerated keyword activity, with the strongest surges in Technology & Data (+350%) and Shopping & Retail (+83%), followed by moderate bursts in Trust & Risk and Marketing & Communication (+67%). Thematic evolution shows 87% growth in Intelligent Commerce & Neuro-Behavioral Analytics in 2024, highlighting the growing integration of technology and consumer psychology. Keyword analysis shows a consistent rise from 2019 and peaking in 2024 with an 86.7% growth in Consumer Psychology, signaling a shift from pandemic-focused research to AI-driven and consumer-centered studies. The findings highlight the transformative impact of IR 4.0 technologies on digital consumer behavior and online commerce research.

Keywords e-commerce, IR 4.0, consumer behavior, bibliometric analysis, online shopping, marketing

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INTRODUCTION

With the advancement of internet technologies and the rise of digital connectivity in the era of the Fourth Industrial Revolution (IR 4.0), online shopping has become a dominant component of modern commerce, facilitating seamless transactions between buyers and sellers (Grover et al., 2025; Huang, 2022). As IR 4.0 integrates technologies like artificial intelligence (AI), big data, IoT, large language models, and smart logistics into e-commerce, online shopping is increasingly seen not only as a commercial activity but also as a field intersecting with technology, operations, behavioral science, and management (Aggarwal, 2023; Benitez et al., 2022). Consequently, related studies are dispersed across a wide range of journals and disciplines, reflecting diverse perspectives and research priorities.

One of the most impactful contributions of IR 4.0 to online shopping is the emergence of intelligent personalization through AI and ma-

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chine learning (Islam et al., 2025; Xu et al., 2024). These technologies power recommendation systems that analyze vast amounts of user data to deliver highly tailored product suggestions (Manish Rai, 2025). Unlike traditional one-size-fits-all marketing, AI-driven personalization creates dynamic shopping experiences that enhancing satisfaction, engagement, and conversion rates (Merfeld et al., 2025). Together, these technologies ensure faster, more reliable, and cost-effective fulfillment, meeting the growing consumer demand for speed, accuracy, and transparency in the digital commerce environment. Enabled by technologies such as cloud computing, mobile commerce, and smart devices, this integration enables consumers to engage with brands through multiple touchpoints in a cohesive and personalized manner. Whether browsing online, purchasing through an app, or picking up in-store, customers experience a unified journey supported by synchronized data and real-time system updates (Ma et al., 2025). This fluid connectivity not only improves convenience and efficiency but also strengthens brand loyalty and consumer trust.

As IR 4.0 continues to evolve, the online shopping ecosystem faces increasing complexity in consumer expectations, data management, and technological integration (Osiyevskyy et al., 2024; Rahman et al., 2025). This convergence of digital innovation and behavioral transformation highlights an urgent scientific problem. It leads that the need to systematically understand how technological advancement redefines consumer behavior, decision-making, and market interaction in the digital era.

1. LITERATURE REVIEW

While the body of literature on online shopping continues to expand, situating this field in a well-structured academic framework proves challenging, particularly in the era of IR 4.0. As IR 4.0 integrates technologies like AI, IoT, big data, large language models, and automation into digital commerce, online shopping increasingly intersects with multiple disciplines, including technology, operations, behavioral science, and management (Ying et al., 2025; Zou et al., 2025). This convergence has led to a wide dispersion of studies across diverse journals, reflecting varying research perspectives, methodologies, and levels of technological focus. As a result, identifying a central or authoritative source for online shopping research becomes difficult, especially for early-career scholars. The multidisciplinary nature of the field under IR 4.0 not only enriches the research landscape but also adds complexity to navigating it, highlighting the need for clearer categorization and interdisciplinary synthesis.

IR 4.0 profoundly affects online shopping by embedding advanced technologies into every stage of the retail process, transforming how businesses operate and how consumers interact with digital platforms (Alhaimer, 2022; Islam et al., 2025). The integration of AI, big data, IoT, and automation enables retailers to offer personalized, efficient, and responsive shopping experiences that were not previously possible (Barata, 2021; Rosário & Raimundo, 2025). These technologies enhance decision-making through real-time analytics, streamline logistics with smart warehousing and automated delivery, and improve customer engagement via personalized recommendations and immersive interfaces like AR and VR (Sharma et al., 2025). Furthermore, cloud computing and mobile technologies support an integrated omnichannel environment, enabling smooth consumer transitions across channels between digital and physical retail environments (Abdallah et al., 2025; Vhatkar et al., 2024). As consumer expectations grow for speed, personalization, and convenience, IR 4.0 equips online retailers with the tools to meet these demands, driving innovation, competitiveness, and sustained growth in the digital commerce landscape (Černý & Gogola, 2023).

The rapid advancement of artificial intelligence, large language models, and interactive chatbots for online purchasing has profoundly reshaped consumer behavior in online shopping (Islam et al., 2025). However, the influence of the IR 4.0 on the analysis of such behavioral changes has not yet been comprehensively examined (Dixit & Prasad, 2025; Li et al., 2023; Rawangngam et al., 2025). To address this gap in the literature, this study employs bibliometric analysis to investigate recent scholarly contributions addressing the impact of

IR 4.0 on online purchasing behavior and to propose a forward-looking research agenda. This work represents the first systematic effort to explore online shopping behavior through the lens of the IR 4.0 and the integration of AI technologies across digital platforms. As online shopping continues to evolve in tandem with IR 4.0, establishing clearer academic boundaries and conceptual frameworks becomes essential for advancing both theoretical understanding and practical applications.

Bibliometric analysis has been used to examine research trends, patterns, and relationships in operation management domain in context of IR 4.0 (Dixit & Prasad, 2025; Zahid et al., 2025). Through an extensive analysis of bibliographic data, this study delineates the major thematic clusters that characterize the evolution and influence of research within this domain. The findings offer a comprehensive understanding of how the field has progressed over time, reveal prevailing scholarly trends, and expose persisting gaps in existing knowledge. Ultimately, the study provides a foundation for guiding future research directions and informs the development of effective strategies to better interpret and address consumer preferences and behavioral dynamics in online shopping operation (Liu et al., 2021; Sordan et al., 2022).

In summary, online shopping behavior has been increasingly influenced by technological factors, as reflected in the growing body of scholarly research. Accordingly, this study employs bibliometric analysis to evaluate the evolution of online shopping research within the context of the IR 4.0, examining how emerging technologies affect consumer purchasing behavior.

The goal is to provide a comprehensive, data-driven overview of how digital commerce is being shaped by technological innovation. By identifying major themes, influential works, and existing research gaps, this review contributes to both academic understanding and practical advancement in this rapidly evolving field.

2. METHODOLOGY

2.1. Data collection

The study follows the PRISMA protocol to ensure transparency and quality in systematic reviews (Page et al., 2021; PRISMA-P Group et al., 2015). Figure 1 illustrates the article selection process using data sourced from the Scopus database. Data are preprocessed and analyzed using the PyBibX package in Python (Valdecy, n.d.), enabling bibliometric analysis and trend identification.

Figure 1 reflects a modernized data-drive approach to systematic reviews. Leveraging digital technologies such as automated database searches, Python scripting, and bibliometric tools developed

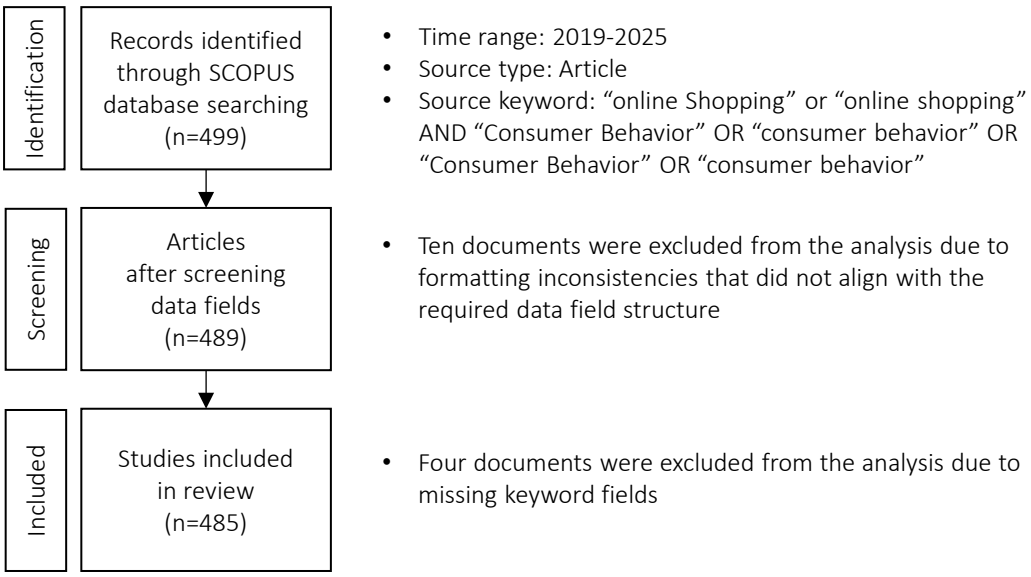

Figure 1. Flow diagram of the literature search and selection

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from PyBibX package, the review process becomes more efficient, transparent, and reproducible. In this study, article identification was streamlined through keyword-based searches on the Scopus database, followed by automated data filtering and cleaning to address formatting inconsistencies and missing fields. The integration of programming tools facilitates in-depth analysis of research trends and key contributors, while visual elements like PRISMA flow diagrams enhance clarity and traceability (Page et al., 2021).

2.2. Data analysis

The study covers the six-year period from 2019 to 2025. The year 2019 was selected as the starting point because it coincides with the onset of the COVID-19 pandemic, a global event that profoundly affected consumer behavior and accelerated the growth of online shopping. A six-year timeframe provides a balanced perspective, allowing the analysis to reflect both immediate variations and enduring trajectories. This duration minimizes the influence of temporary anomalies while offering a more stable representation of evolving patterns. Furthermore, the period encompasses significant advancements in technology, shifts patterns in consumer sentiment and emerging emphases in academic research, making it a suitable window for examining the dynamic transformation of online shopping behavior.

The dataset spans from 2019 to 2025 and includes 485 documents contributed by 1,431 authors as shown in Figure 2. Among these, 447 are multi-authored and 38 are single-authored papers. The research covers 73 countries and 913 institutions, drawing from 280 publication sources and referencing a total of 29,816 works. Additionally, the documents collectively contain 1,717 author keywords, highlighting active scholarly engagement.

3. RESULTS

3.1. Performance analysis

The study employs two key quantitative metrics, documents per year and citations per year (Donthu et al., 2021; Mahendra & Yoshiki, 2015) to assess research performance in the field of online consumer purchasing patterns, framed within the context of IR 4.0. A central goal of this analysis is to measure research output, recognize leading contributions, and trace intellectual growth within the field (Donthu et al., 2021). Figure 3 visualizes publication and citation dynamics, reflecting the evolution and influence of research across years.

Figure 3 visualizes the research developments on online shopping customer behavior between 2019 and 2025, reflecting broader trends influenced by

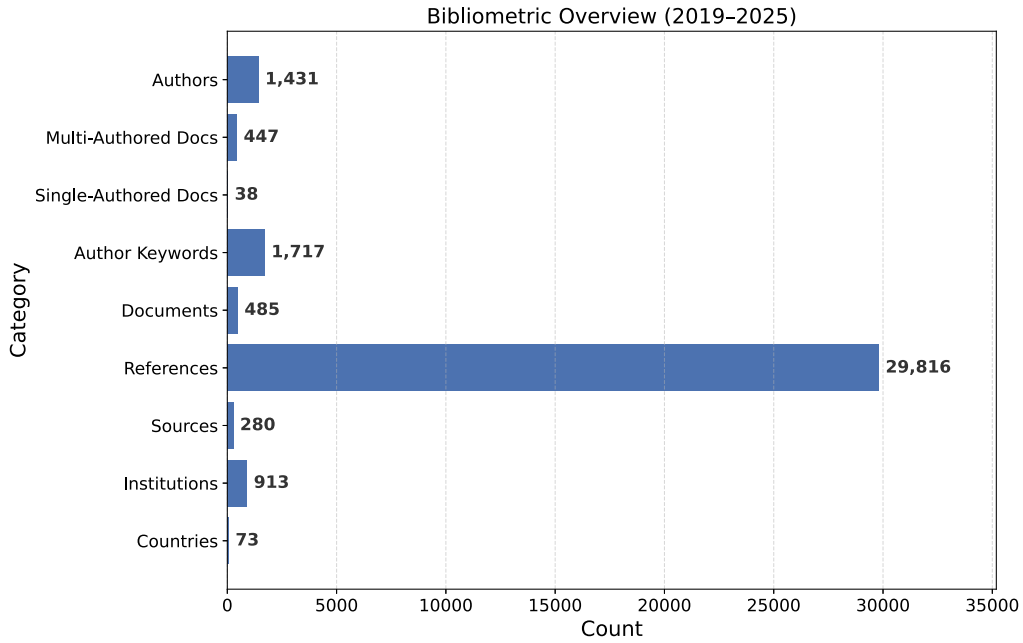

Figure 2. Bibliometric overview (2019-2025)

IR 4.0. During the early years, particularly from 2019 to 2022, there was a steady rise in the number of publications, peaking at 84 documents in 2022, largely driven by the COVID-19 crisis and the rapid advancement of digital technologies. This surge aligns with increased interest in AI-driven personalization, e-commerce platforms, and data analytics, core components of IR 4.0. The number of studies rose by 19.6% in 2020, 10.9% in 2021, and peaked with a 37.7% increase in 2022, marking the field's most active growth phase. A slight decline of 3.6% in 2023 was followed by a rebound of 29.6% in 2024, driven by AI-related topics. The apparent 49.5% drop in 2025 results from incomplete indexing rather than reduced research activity. The publication output grew from 46 (in 2019) to 105 papers (in 2024), corresponding to a compound annual growth rate 17.9%/year when topics related to artificial intelligence, big data, and smart consumer behavior became prominent within the context of the IR. From 2019 to 2025, the average citation rate per document in online shopping behavior research reached 19.8 citations per paper, indicating a strong scholarly impact compared with the typical 10-12 citations observed in social science and marketing fields (Bornmann & Mutz, 2015; Waltman & Van Eck, 2013). The highest averages occurred between 2019 and 2021 (over 30 citations per paper), reflecting the strong influence of early COVID-19 and digital transformation studies. However, while publication output remained high through 2024, citations began to decline significantly after 2022, suggesting a lag in scholarly impact or a shift in research focus toward online shopping topics.

The high publication in 2024 indicates academic attention to newer innovations such as autonomous commerce, AR/VR shopping, or blockchain applications. This pattern reflects how research is continuously evolving and adapting within the IR 4.0 framework, where relevance and impact are closely tied to technological advancement.

The chart shows that the field is expanding, with the number of publications increasing rapidly. However, the impact of recent studies remains relatively low due to the natural citation delay and the growing fragmentation of research topics.

3.2. Keyword analysis

To explore keyword evolution over time, Figure 4 presents the top 50 bi-gram keywords per year, categorized into seven thematic groups: Shopping & Retail, E-Commerce & Platforms, Consumer Psychology, Trust & Risk, Marketing & Communication, Technology & Data, and Other. This Natural Language Processing-based analysis reveals shifting research trends and emerging topics in online consumer behavior (Mikolov et al., 2013). Shopping & Retail reflects digital transformation through terms like online shopping and grocery shopping, while Consumer Psychology

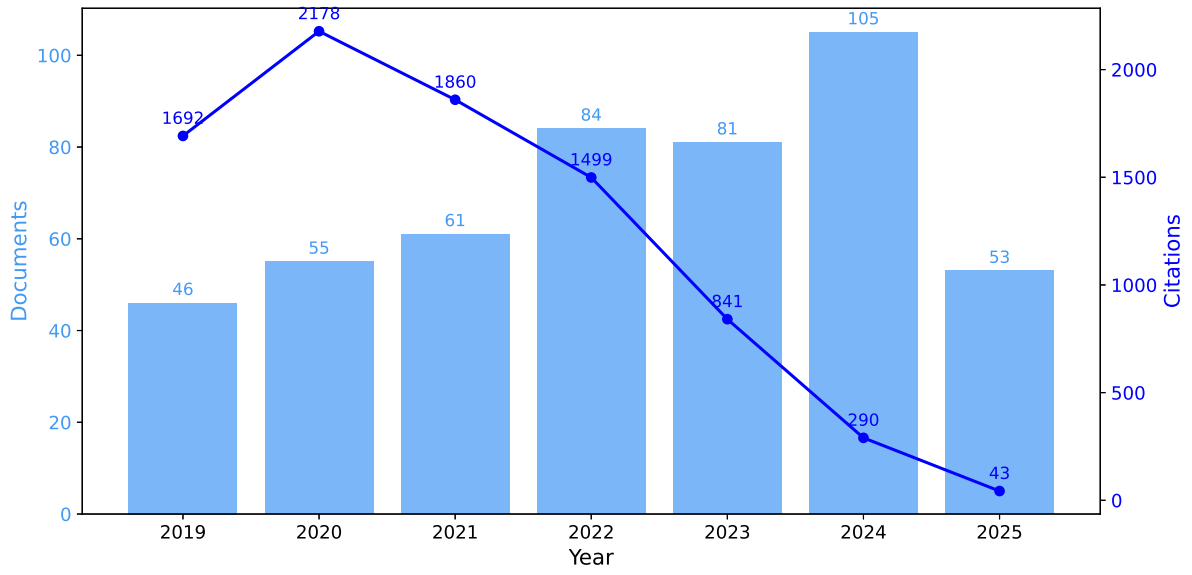

Figure 3. Yearly trends in number of documents and citations (2019-2025)

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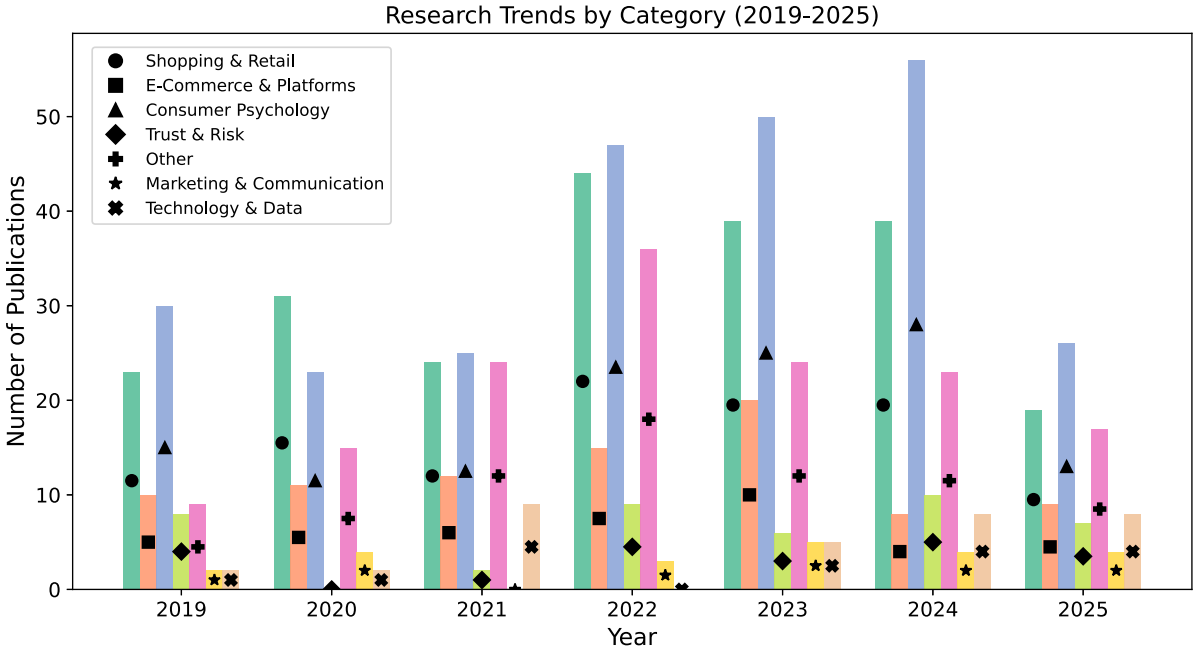

Figure 4. Top 50 different keywords are categorized into seven groups over years

emphasizes decision-making and satisfaction influenced by AI and neuromarketing. E-Commerce & Platforms highlights the digital infrastructure of marketplaces, and Trust & Risk focuses on privacy and security concerns. Marketing & Communication captures social media's role in personalized engagement, and Technology & Data includes innovations like machine learning, AI, and augmented reality. The Other group addresses broader influences such as COVID-19 and sustainability. Together, these categories illustrate how IR 4.0 technologies are reshaping consumer research and behavior.

As shown in Figure 4, the grouped bar chart illustrates the evolution of keyword groups in online shopping research between 2019 and 2025. Consumer Psychology emerges as the most dominant theme, with a steady increase from 2019, rising from 30 to 56 bi-gram keywords (+86.7%) and peaking in 2024, reflecting the growing academic interest in attitudes, decision-making, and user experiences within digitally mediated commerce. E-Commerce & Platforms expanded steadily from 10 to 20 in 2023 (+100%). Shopping & Retail grew from 23 to 44 (+91.3%) in 2022, showing a notable spike coinciding with the COVID-19-driven acceleration of e-commerce, and remains consistently high, highlighting the sustained relevance of retail transformation under IR 4.0. Trust & Risk, though less emphasized overall, gains renewed attention in 2024 and 2025 (+66.7%) as privacy, security, and ethical concerns become central to digital commerce. Meanwhile, Technology & Data gradually rises, particularly in 2021 and again in 2024-2025, underscoring the integration of AI, machine learning, and immersive technologies into consumer research. The Other category peaks in 2022-2023, driven by contextual factors such as the pandemic and demographic influences, but declines afterwards as research focus shifts back to consumer-centric and technology-driven themes.

Throughout the years, online shopping and e-commerce have maintained their prominence in scholarly discourse, reflecting the ongoing expansion of digital markets under the influence of IR 4.0 technologies. Consumer behavior has remained a central theme, with continuous scholarly attention highlighting the importance of understanding how digital technologies shape purchasing patterns. Since 2021, the influence of the COVID-19 pandemic has become increasingly apparent, particularly during 2022 and 2023, when it significantly altered consumer priorities and online shopping dynamics. In recent years, growing emphasis has been placed on customer experience and satisfaction, as organizations strive to enhance digital engagement and service quality. A

Table 1. The comparison of burst strength in burst detection

Thematic Group	Peak year	Frequency (peak)	Previous year	Frequency (previous)	Burst strength (%)	Interpretation
Shopping & Retail	2022	44	2021	24	83.3%	Strong burst from COVID-19 e-commerce boom
E-Commerce & Platforms	2023	20	2022	15	33.3%	Moderate post-pandemic platform expansion
Consumer Psychology	2024	56	2023	50	12.0%	Gradual behavioral research growth
Trust & Risk	2024	10	2023	6	66.7%	Rising focus on AI-driven trust and privacy
Other	2022	36	2021	24	50.0%	COVID-19 and sustainability surge
Marketing & Communication	2023	5	2022	3	66.7%	Increase in social media and engagement topics
Technology & Data	2021	9	2020	2	350.0%	Sharp burst due to AI, ML, and AR/VR integration
Mean Burst Strength	–	–	–	–	94.6%	Average burst intensity across themes

subtle shift observed in 2024 and 2025 indicates a narrowing of thematic diversity; however, strong research interest persists in online shopping, trust, and customer experience, key dimensions driving the evolution of e-commerce in the IR 4.0 era.

To uncover emerging hot topics, the burst detection is conducted that identifies time intervals where the frequency of a keyword rises unusually quickly relative to its baseline trend. In Kleinberg's burst detection model, burst strength quantifies how sharply a topic's frequency rises above its baseline, signaling sudden research attention. It can be approximated by the relative growth rate between a topic's peak year and the preceding year. Higher burst strength values indicate stronger and faster-emerging research themes (Chen, 2006).

Table 1 demonstrates clear variations in burst intensity across the seven thematic groups, reflecting how research attention has shifted during 2019-2025 under the influence of Industry 4.0. The average burst strength of 94.6% indicates that publication activity in these themes experienced a strong acceleration rather than a steady linear rise. The most striking surge appears in Technology & Data (350%), showing the explosive growth of studies on AI, machine learning, and AR/VR integration into online shopping contexts. Shopping & Retail (83.3%) and Trust & Risk (66.7%) also exhibit robust bursts, corresponding to the pandemic-driven e-commerce boom and subsequent focus on consumer trust and data privacy. Moderate but sustained bursts in Marketing & Communication (66.7%) and Other (50%) suggest the diversification of research toward social engagement, sustainability, and contextual factors such as COVID-19. In contrast, Consumer Psychology (12%) and E-Commerce & Platforms (33.3%) show weaker bursts, implying more stable, mature areas of inquiry. Collectively, these results reveal a distinct temporal pattern: early attention concentrated on e-commerce infrastructure, while recent years show intensified interest in technology-driven, behavior-focused, and trust-related themes, confirming the transformative impact of IR 4.0 on online consumer behavior research.

3.3. Cluster analysis

The study applies the Document-Term Matrix (DTM) algorithm-based Python tool for science mapping analysis (Aria & Cuccurullo, 2017), which operates by analyzing the similarity between keywords in documents, thereby proposing five clusters as presented in Table 2. From this, the top 50 keywords for each cluster are extracted to analyze user behavior in online shopping from the perspective of IR 4.0 by N-gram technique (Manning et al., 2008). Author keywords are grouped into distinct sets in each cluster for further analysis.

Group 1: Consumer behavior and smart retail channels in the era of IR 4.0

This first cluster highlights the transformation of consumer behavior and retail channels through the integration of digital technologies, data-driv-

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en decision-making, and smart logistics systems (Tan et al., 2025; Vhatkar et al., 2024). The online shopping keyword group including online shopping, e-commerce, behavior online, and digital marketing reflect how businesses are leveraging automation, artificial intelligence, and real-time analytics to personalize the customer journey and optimize engagement (Nguyen et al., 2025). Consumer behavior concepts like purchase intention, omni-channel, and commerce platform indicate a shift toward seamless, interconnected retail ecosystems, where physical and digital touchpoints are unified (Li et al., 2020). Furthermore, the inclusion of logistics terms like supply chain, last mile, and strategy online emphasizes the role of smart logistics and IoT-enabled supply chains in meeting evolving customer expectations (Hur & Won, 2024). This cluster encapsulates how IR 4.0 technologies are reshaping commerce, empowering businesses to deliver responsive, data-informed, and customer-centric retail experiences.

Group 2: Behavioral insights and intelligent commerce in the IR 4.0 era

This cluster captures the convergence of digital consumer behavior, perceived risk, and intelligent commerce systems enabled by emerging technologies (Ma et al., 2025; Tan et al., 2025). The highest frequency keywords such as online shopping, online purchase, shopping cart, and cart abandonment reflect the evolution of e-commerce into a data-driven, behavior-aware ecosystem, where real-time tracking and predictive analytics optimize the customer journey. Concepts like perceived value, purchase intention, and trust perceived demonstrate the increasing reliance on consumer-centric insights to tailor marketing strategies and design adaptive user experiences (Nuralam et al., 2024; Srivastava & Thaichon, 2023). Moreover, the presence of terms such as structural equation modeling, planned behavior, and behavioral intention highlights a solid analytical foundation for examining online purchasing decisions, increasingly supported by advancements in big data analytics and machine learning techniques. (Huseynov & Özkan Yıldırım, 2019). Elements related to cross-border commerce, online grocery, and service providers signal a globalized, automated retail environment shaped by smart logistics and interconnected platforms. This cluster exemplifies how IR 4.0 is reshaping commerce through advanced behavioral modeling, intelligent infrastructure, and customer-centric innovation.

Group 3: Data-driven consumer behavior and digital commerce in the age of IR 4.0

This cluster illustrates how emerging technologies are transforming the landscape of consumer behavior research, e-commerce, and public health-related consumption. Terms with 80 online-shopping and 88 customer-behavior mentions reflect the growing influence of data-driven personalization, while machine learning, data mining, and big data emphasize the analytical tools powering behavioral prediction and market segmentation (Heidary Dahooie et al., 2021; Maulidi et al., 2024). The cluster also reveals a strong presence of demographic profiling (e.g., middle aged, young adult, female humans), aligned with intelligent systems that adapt to consumer diversity in real-time. The inclusion of terms like covid 19, pandemic, food consumption, and health care underscores how IR 4.0 technologies were leveraged during crises to understand and respond to changes in consumer needs, digital health services, and grocery logistics (Katare et al., 2025). Additionally, references to electronic commerce, shopping pandemic, and commerce consumer highlight how automated commerce platforms, powered by AI and the Internet of Things (IoT), are central to the modern retail experience (Kim & Chang, 2024). This cluster represents the convergence of intelligent technology, behavioral science, and digital consumption, which lies at the heart of IR 4.0's impact on retail and society.

Group 4: Smart consumer experience and digital commerce innovation in IR 4.0

In the context of IR 4.0, this cluster encapsulates the integration of smart technologies, customer experience management, and behavioral analytics into the fabric of modern digital commerce (Sahli & Lichy, 2024). Central high frequency terms reflect a strong focus on understanding and optimizing the digital customer journey through real-time data, machine learning, and artificial intelligence. Keywords like augmented reality, virtual try, and flow experience suggest immersive technologies reshaping how consumers interact with online

platforms (Rumman et al., 2024; Kurniawati et al., 2024). Moreover, the presence of technology acceptance, user experience, and structural equation modeling reveals the analytical frameworks and modeling tools being applied to evaluate consumer readiness and adoption of digital interfaces. Meanwhile, social commerce, digital marketing, and commerce emerging point to a dynamic ecosystem of multi-channel digital engagement, where personalization and intelligent automation drive competitive advantage (Lin & Wang, 2023). As a whole, this cluster represents a convergence of digital technologies, psychological modeling, and customer-centric design, highlighting how IR 4.0 is transforming not only how consumers buy, but how businesses understand and shape that behavior (Yang & Lin, 2024).

Group 5: Neuro-behavioral analytics and smart shopping behavior in the IR 4.0 era

This cluster reflects a nuanced exploration of consumer psychology, neuro-driven marketing, and intelligent shopping behavior in digitally enhanced retail environments (Najafabadiha et al., 2025). With terms such as online shopping, purchase intention, online marketing, and online purchase, the cluster highlights how digital platforms are being optimized using AI, real-time analytics, and user-generated data to personalize the customer journey (Johnson et al., 2022; Modi & Singh, 2023). Concepts like impulsive buying, compulsive buying, shopping addiction, and loyalty online point to the application of behavioral and cognitive science, aided by technologies like eye tracking, visual attention analysis, and neuromarketing, to understand subconscious drivers of purchase. The inclusion of hedonic value, utilitarian value, consumer neuroscience, and experience online signals a focus on the emotional and experiential aspects of digital consumption, core to IR 4.0's user-centric design. Altogether, this cluster demonstrates how technologically enhanced consumer insight, supported by neurophysiological and behavioral data, is reshaping how businesses design, influence, and sustain engagement in the digital commerce era.

The co-word network reveals a clear core-periphery structure in online shopping research as shown in Figure 5. At the center, online shopping and consumer behavior function as permanent anchors, appearing across all clusters and providing the intellectual backbone of the field. Around this core, purchase intention emerges as a strong psychological bridge linking themes of trust, risk, experience, and impulse buying, while technology-related keywords demonstrate the pervasive role of innovation across multiple clusters. COVID-19 acts as a transversal but temporary connector, influencing retail, demographics, and behavioral studies during its peak. Meanwhile, emerging topics such as impulse buying, word of mouth, and sustainability occupy more peripheral positions,

Table 2. Thematic groups

Group 1 (n=107)		Group 2 (n=107)		Group 3 (n=96)		Group 4 (n=103)		Group 5 (n=72)	
Keyword	**Count**	**Keyword**	**Count**	**Keyword**	**Count**	**Keyword**	**Count**	**Keyword**	**Count**
Online Shopping	102	Online Shopping	97	Consumer Behavior	88	Online Shopping	80	Online Shopping	60
Consumer Behavior	83	Perceived & Risk	56	Online Shopping	80	Consumer Behavior	54	Consumer Behavior	39
Marketing	33	Consumer Behavior	53	COVID-19	76	Marketing	46	Impulse Buying	20
Logistics	18	Technology/Models	43	Demographics	71	Technology	34	Technology/ Tracking	18
Purchase Intention	17	Purchase Intention	19	Food & Health	33	Customer Experience	28	Word of Mouth	17
COVID-19	12	Commerce	16	Business/ Commerce	27	Quality	22	Hedonic/ Utilitarian	14
Commerce	9	COVID-19	15	Technology	20	Research/Models	22	Purchase Intention	12
Other	11	Services & Management	13	Perception & Judgment	18	Purchase Intention	14	Commerce	4
		Other	8	Research Methods	7	Other	7	COVID-19	3
				Other	12	COVID-19	5	others	15
						Sustainability	4		

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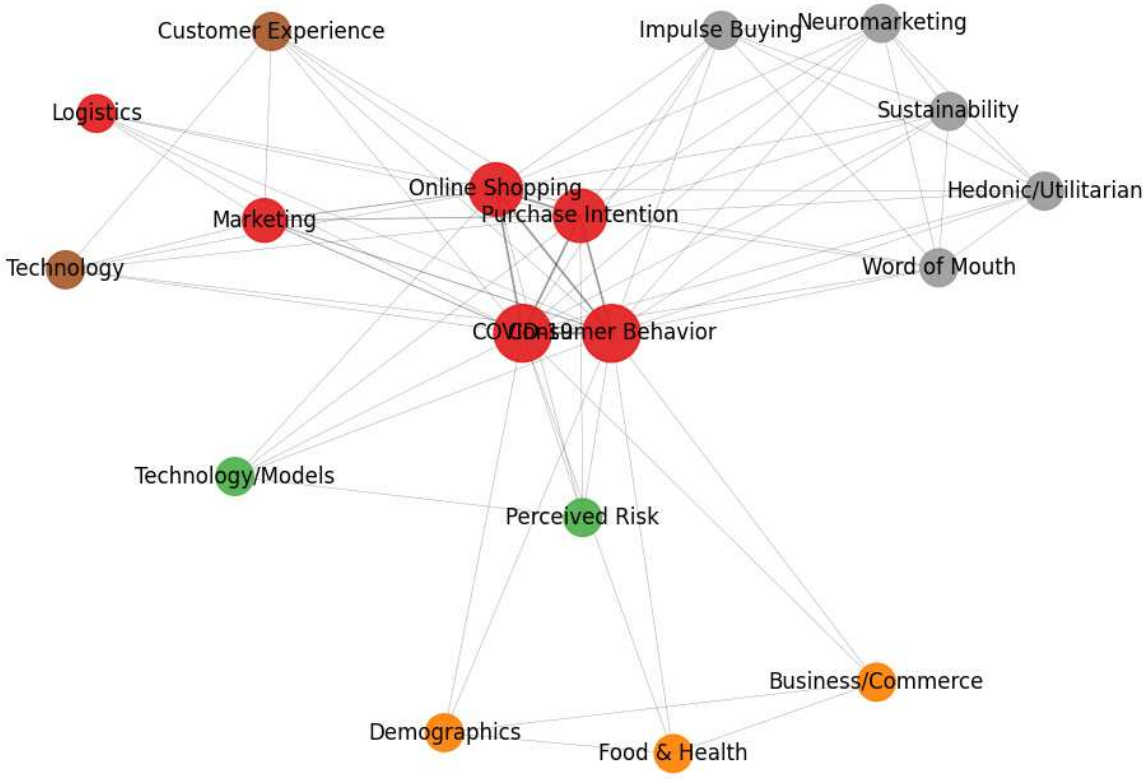

Figure 5. Co-word network of five clusters in online shopping research in IR 4.0

reflecting niche or developing research frontiers that may gain prominence in future studies.

The five clusters highlight how IR 4.0 technologies are transforming consumer behavior and retail operations, with a strong emphasis on personalization, data-driven decision making, and the convergence of online and offline channels to enrich customer experiences in the digital era.

3.4. Thematic evolution analysis

This study employs a thematic evolution analysis to capture the temporal dynamics of research themes (Donthu et al., 2021). By combining yearly keyword frequency (n-grams) with cluster structures derived from the DTM, the analysis identifies not only the static thematic composition of the field but also its evolution over time. This approach enables the mapping of how research emphasis shifts across clusters, revealing emerging, declining, and persistent themes in online shopping behavior within the Industry 4.0 context as shown in Figure 6.

In Figure 6, the yearly evolution of keywords reveals clear patterns of growth and decline across clusters. Consumer Psychology such as purchase intention, trust, risk perception, behavioral intention, aligns closely with cluster 2 (Intelligent Commerce) and cluster 5 (Neuro-behavioral Analytics), reaching a peak in 2024 as post-COVID research placed greater emphasis on psychological and experiential dimensions. Shopping & Retail/E-Commerce & Platforms such as online shopping, supply chain, omni-channel, map directly onto cluster 1 (Consumer Behavior & Smart Retail), with a notable surge in 2022 reflecting the implications of the COVID-19 crisis for digital retailing infrastructure studies. Technology & Data such as machine learning, data mining, AR/VR, connect with cluster 3 (Data-Driven Behavior) and cluster 4 (Smart Experience), showing strong growth in 2021 and again in 2024-2025, highlight-

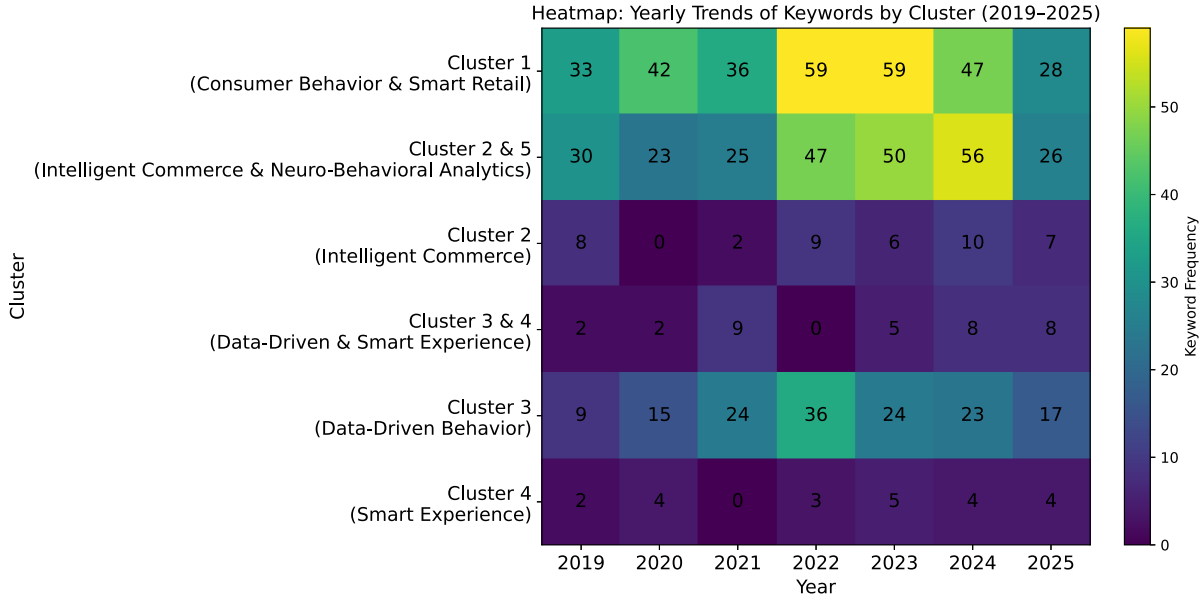

Figure 6. Heatmap: yearly trends of keywords by cluster (2019-2025)

ing the increasing role of AI, ML, and AR/VR. Trust & Risk, situated within cluster 2, becomes particularly salient in 2024-2025 as the rapid expansion of e-commerce brought concerns over security and consumer trust to the forefront. Finally, Other themes such as COVID-19, demographics, and sustainability serve as supporting threads that link multiple clusters, especially cluster 3, which reflects data-driven studies during crisis contexts.

The heatmap also illustrates the temporal distribution of keyword clusters and clearly reflects the shifting focus of online shopping research within the context of Industry 4.0 in the Figure 6. During 2020-2022, cluster 1 (Consumer Behavior & Smart Retail) dominates the field, accounting for the highest activity with a peak of 59 keywords in 2022-2023 and maintaining over 25% of total keyword frequency throughout the period, as e-commerce and contextual factors such as COVID-19 became central topics. Clusters 2 and 5 (Intelligent Commerce & Neuro-Behavioral Analytics) shows a strong upward trajectory, rising from 30 keywords in 2019 to a peak of 56 in 2024, an 87% increase, reflecting growing attention to trust, purchase intention, and neuro-marketing. In contrast, clusters 3 and 4 (Data-Driven & Smart Experience) and cluster 3 (Data-Driven Behavior) display moderate but steady growth, with frequencies rising by 60-80% between 2019 and 2024 as AI, ML, and AR/VR integration gained prominence. This evolution demonstrates how the field is moving away from an initial focus on infrastructure and crisis-driven themes toward a stronger emphasis on consumer experiences, advanced technologies, and psychological aspects of digital commerce.

4. DISCUSSION

The findings reveal that research on online shopping behavior within the context of IR 4.0 has evolved significantly, shifting from foundational studies on digital adoption toward more complex, multidisciplinary investigations into consumer psychology, technological integration, and personalized experiences. The steady rise in publications, especially during the pandemic, highlights increased academic interest in AI-driven personalization, smart retail systems, and data-informed consumer engagement. However, the decline in citation trends suggests a saturation of early themes and a pivot toward emerging areas such as immersive technologies (AR/VR), neuromarketing, and behavioral analytics.

Keyword and thematic clustering analysis further confirms this shift, with growing attention to emotional, cognitive, and trust-related factors in digital commerce. The five identified clusters re-

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flect the diversification of the field, encompassing intelligent logistics, consumer neuroscience, user experience modeling, and ethical concerns around data use. The results reveal both the structural consistency and dynamic transformation of the field. Online shopping and e-commerce continue to form the intellectual core of this research domain, yet the surrounding themes have diversified substantially, reflecting the increasing influence of artificial intelligence, data analytics, and digital consumer psychology. The identification of five major thematic clusters demonstrates how scholarship has progressed from foundational studies of digital retail infrastructure toward more human-centered and technology-integrated investigations.

The burst detection and thematic evolution analyses confirm this transition, showing that technological themes such as machine learning, AR/VR, and neuromarketing have gained increasing prominence. These technologies are reshaping how consumers perceive, interact with, and make decisions in online environments. The rise of neuro-behavioral analytics suggests a growing effort to understand subconscious and emotional drivers of purchase behavior, bridging insights from cognitive neuroscience and marketing. This trend aligns with global digitalization and reflects a maturing interdisciplinary approach that combines behavioral theory with data science.

When compared with earlier bibliometric and systematic reviews the present study reveals a broader thematic scope and stronger integration of behavioral and technological perspectives. Previous analyses largely focused on traditional e-commerce factors such as perceived usefulness, risk, and loyalty (Dixit & Prasad, 2025; Li et al., 2023; Rawangngam et al., 2025; Srivastava & Thaichon, 2023), while overlooking emerging technologies like machine learning, AR/VR, and neuromarketing. This study extends prior work by demonstrating how these technologies now shape the field's evolution, shifting emphasis from infrastructure and transactional systems toward cognitive, emotional, and experiential dimensions of consumer behavior.

Consistent with Dixit and Prasad (2025), our findings confirm the transformative role of the IR 4.0, though we identify a pronounced shift from operational resilience to consumer engagement. Similarly, aligning with Li et al. (2023), who underscored the role of risk and trust in live-streaming commerce, this study finds the Trust & Risk domain resurging within a broader AI-driven ecosystem. In relation to Srivastava and Thaichon (2023), who examined motivational factors in online shopping adoption, our bibliometric analysis expands their perspective by capturing the temporal evolution of consumer psychology and technology integration from 2019-2025. Both studies emphasize trust, satisfaction, and intention, but our results situate these within modern digital architectures, offering a dynamic view of how AI, data analytics, and immersive technologies redefine consumer engagement in the IR 4.0 era. Compared with Rawangngam et al. (2025), the authors analyzed social media-driven consumer engagement across six clusters emphasizing brand interaction, loyalty, and digital marketing communication, our study adopts a broader perspective encompassing the entire landscape of online shopping and digital commerce. While both studies underscore engagement and trust as central themes, this present research extends the discussion by introducing a longitudinal, technology-focused view that highlights how AI, IoT, and data analytics increasingly drive personalization and consumer connection across retail platforms. Through document-term matrix modeling, thematic evolution, and burst detection, the study reveals the temporal dynamics of the field and the rising convergence of consumer psychology with immersive digital technologies.

Future research in the context of IR 4.0 should focus on how advanced technologies are reshaping consumer behavior and digital commerce. Building on identified clusters, studies should explore how AI, IoT, and real-time analytics improve omnichannel integration, logistics, and personalization. Research is needed on behavioral models that reduce cart abandonment, foster trust, and adapt to diverse consumer profiles. As AR and VR gain popularity, their impact on engagement and purchase intention, especially in fashion and home retail, should be assessed. Additionally, neuromarketing and emotion-aware systems offer potential to uncover subconscious drivers of behavior, though ethical issues like privacy and transparency must be addressed. Cross-cutting themes such as sustainability, adaptive interfaces, and explainable AI also warrant attention to ensure innovation aligns with responsible practices. Ultimately, understanding these dynamics

will help businesses optimize engagement, improve satisfaction, and succeed in a rapidly evolving digital landscape.

In summary, the discussion underscores that online shopping behavior research has entered a new phase characterized by digital intelligence, consumer-centric design, and interdisciplinary integration. Future work should continue to examine how AI-driven systems, immersive technologies, and sustainability imperatives collectively redefine consumer behavior in the digital economy of the IR 4.0 era.

CONCLUSION

The purpose of this study was to systematically analyze and quantify the evolution of online shopping behavior research within the framework of the IR 4.0 from 2019 to 2025. The results reveal a marked intensification of research activity, with a mean burst strength of 94.6% and significant surges in Technology & Data (+350%) and Shopping & Retail (+83%). Publication output peaked in 2022 (+37.7%), while thematic evolution domains such as Intelligent Commerce & Neuro-Behavioral Analytics expanded by over 85%, and keyword trends in Consumer Psychology grew by 86.7%, reflecting the increasing influence of artificial intelligence, machine learning, and immersive technologies. Five major thematic clusters were identified: Consumer Behavior & Smart Retail, Intelligent Commerce, Data-Driven Behavior, Smart Experience, and Neuro-Behavioral Analytics, which collectively illustrate a temporal shift from pandemic- and infrastructure-focused studies (2020-2022) to technology-driven and consumer-centered research (2023-2025). These findings confirm a structural transformation in the field, highlighting the growing convergence of behavioral science and technological innovation. Building on these insights, future research should integrate bibliometric and computational methods, such as machine learning and sentiment analysis, to anticipate emerging topics and reveal hidden behavioral patterns. Moreover, incorporating cross-cultural, ethical, and sustainability perspectives will be vital to ensure that the continued evolution of digital commerce under IR 4.0 remains inclusive, responsible, and aligned with long-term societal and environmental goals.

AUTHOR CONTRIBUTIONS

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Formal Analysis: Hanh Vo Thi Xuan.
Investigation: Hanh Vo Thi Xuan.
Resource: Hanh Vo Thi Xuan.
Data Curation: Hanh Vo Thi Xuan.
Writing-Original Draft: Hanh Vo Thi Xuan, Vo Minh Huan.
Writing & Review Editing: Hanh Vo Thi Xuan, Le Hoanh Su, Vo Minh Huan.
Visualization: Hanh Vo Thi Xuan.
Supervision Le Hoanh Su, Vo Minh Huan.
Project Administrator: Le Hoanh Su, Vo Minh Huan.
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