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Bibliometric Analysis of Aspect-based Sentiment Analysis Research: Trends, Challenges, and Future Directions

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Abstract: Aspect-Based Sentiment Analysis (ABSA) has become an integral component of Natural Language Processing (NLP). It provides comprehensive insights into individuals' sentiments regarding specific aspects. This study conducts a comprehensive bibliometric analysis of 913 journal articles published from 2010 to 2024, sourced from the Scopus database, to examine trends, challenges, and prospective directions in ABSA research. The research examines the expansion of publications, citation metrics, and scholarly networks. It integrates performance analysis metrics (such as h-index, g-index, and citations per paper) with sophisticated science mapping techniques, including keyword co-occurrence networks, thematic evolution, and thematic mapping. This novel integrated approach, rarely employed in prior ABSA bibliometric studies, reveals both historical trends and emerging niche themes that remain underexplored. The findings illustrate the evolution of ABSA from rule-based methodologies to transformer-based architectures applicable in e-commerce, social media, and customer feedback systems. Key issues identified include multilingual adaptability, implicit sentiment detection, and cross-domain scalability. The research indicates that global institutions have significantly contributed, yet productivity and impact differ markedly across nations. Multimodal analysis, transfer learning, and contextualized models such as BERT are pivotal contemporary methodologies that can assist in addressing existing challenges. Future research should concentrate on integrating diverse disciplines, analyzing data across various languages and modalities, and developing scalable and comprehensible models. This study contributes to the domains of artificial intelligence and sentiment analysis by offering a comprehensive and data-driven overview of the ABSA landscape. It accomplishes this by providing both strategic insights and methodological enhancements.

Index Terms: Aspect-Based Sentiment Analysis, Bibliometric Analysis, Opinion Mining, Sentiment Analysis Trends.

1. Introduction

ABSA has revolutionized the field of NLP and Artificial Intelligence (AI) by enabling fine-grained sentiment interpretation that is tied to specific aspects or components of entities, such as products, services, or topics. This aspect-level sentiment granularity marks a significant advancement over traditional sentiment analysis approaches, which typically offer a coarse, document or sentence-level polarity classification. Unlike conventional methods, ABSA dissects opinions to target-specific attributes within text, yielding deeper insights into customer or user satisfaction [1,2]. This capability has been increasingly essential in domains like e-commerce, hospitality, and social media analysis, where opinions often span multiple aspects with contrasting sentiments [3]. Recent studies highlight the integration of

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deep learning architectures, such as CNN and LSTM, for effective ABSA implementations, further pushing the boundaries of sentiment analysis through the ability to capture both local features and long-term dependencies [4].

ABSA's capability to extract opinions on individual features such as battery life in a smartphone review or customer service in hotel feedback makes it increasingly vital for a range of domains, including e-commerce, finance, politics, and healthcare. With the explosion of user-generated content across platforms like online reviews and social media, understanding not just what people feel but what they feel about is critical [5,6]. Consequently, ABSA plays a strategic role in supporting decision-making processes, enhancing customer experience, and driving product development. Despite its growing relevance, however, the landscape of ABSA research remains fragmented, with limited synthesis of evolving trends, key contributors, and thematic shifts [7,8]. A comprehensive bibliometric analysis is thus essential not only to map the historical and current research trajectory but also to identify gaps, evaluate methodological advances, and guide future innovations in this rapidly expanding field. In parallel, bibliometric analysis emerges as a critical tool for understanding the trajectory of ABSA research, offering insights into key trends, influential authors, and collaborative networks.

Through systematic evaluation of publications, bibliometric analysis reveals emerging themes, assesses the impact of methodologies, and identifies gaps in the literature [9,10]. This analysis not only traces the evolution of ABSA research but also sheds light on the collaborative dynamics among researchers and institutions, fostering a more interconnected academic community [11,12,13]. As the field grows, bibliometric analysis will guide future research directions, informing both academia and industry stakeholders about advancements in sentiment analysis [14,15,16]. Framing key research questions is essential for a comprehensive bibliometric analysis of ABSA. These questions include identifying prevailing trends in ABSA publications over time, pinpointing influential authors and journals, and uncovering collaborative networks among researchers. Additionally, the analysis seeks to identify research gaps and propose actionable directions to address unresolved challenges and advance the field [17,18,19]. These focused inquiries will enable a thorough exploration of ABSA's research landscape, aligning the study's objectives with its broader goals.

This study's objectives align closely with these research questions, emphasizing trends, contributors, and gaps in ABSA research. The study will first chart trends in ABSA publications over time, analyzing citation metrics and the emergence of new methodologies and applications [20,21]. It will then identify influential authors, journals, and collaborations, mapping the academic landscape to highlight contributions that have shaped ABSA research [22,23]. Finally, the study aims to uncover gaps in the existing literature, offering actionable recommendations to address these gaps and guide future advancements in ABSA [24,25]. Bibliometric analysis offers diverse benefits to the ABSA domain, supporting researchers, institutions, and industry stakeholders. For researchers, it identifies promising topics and gaps, enabling more focused and impactful studies [26,27]. For institutions, it highlights collaborative opportunities to enhance research output and influence [28,29]. Industry stakeholders also benefit, as insights into consumer sentiments and preferences enable data-driven decision-making [30,31]. By bridging these perspectives, bibliometric analysis serves as a strategic framework to propel ABSA research and its real-world applications.

Therefore, this bibliometric analysis aims to provide a systematic and data-driven exploration of the ABSA research landscape over the past decade. The main objective of this study is to uncover publication trends, leading contributors, and thematic developments while simultaneously identifying underexplored areas that present opportunities for future research. This study is novel due to its distinctive methodology, which integrates comprehensive performance metrics (such as h-index, g-index, and citation metrics) with sophisticated science mapping techniques (including keyword co-occurrence network analysis, thematic evolution, and thematic mapping). Previous bibliometric investigations in ABSA have predominantly focused on limited aspects, such as descriptive statistics or a singular analytical dimension. This study adopts a comprehensive and integrated methodology by utilizing a significantly larger and more current Scopus dataset (913 journal articles from 2010 to 2024), thereby providing more detailed and nuanced insights. This study elucidates themes that have been insufficiently explored, such as multimodal and multilingual ABSA. This informs subsequent research and enhances our comprehension of both theory and practice. This article serves as a fundamental reference for comprehending the evolution of ABSA, its status, and potential strategic advancements in the forthcoming years [32,33].

2. Literature Review

ABSA has become a focal point in sentiment analysis research due to its ability to provide detailed insights into consumer opinions across various domains, such as product reviews and social media interactions. Unlike traditional sentiment analysis, ABSA focuses on specific aspects of entities, enabling a more precise understanding of user sentiments [1,18,34]. This fine-grained analysis allows businesses to customize their offerings based on detailed feedback, improving customer satisfaction [26]. Recent advancements in ABSA methodologies, particularly the adoption of deep learning techniques, have significantly enhanced sentiment classification accuracy and efficiency [7,22]. For instance, Ma [5] proposed an interactive learning network that ensures sentiment consistency, while [35,36] introduced a domain-adaptive, multi-feature fusion approach to improve sentiment extraction. Despite these developments, challenges like domain specificity and the need for large labeled datasets remain significant hurdles [36].

The integration of attention mechanisms and multimodal approaches further highlights the evolving landscape of ABSA. Attention-based models have proven crucial for identifying contextual relevance within reviews, enhancing the accuracy of aspect-level sentiment classification [33]. However, these mechanisms often lack interpretability, making it difficult to validate their decision-making processes [37]. Additionally, multimodal approaches that incorporate text and image data aim to enrich sentiment analysis but require sophisticated models to process and integrate diverse data sources effectively [17,38,39]. Domain-specific applications, such as in hospitality and tourism, underscore the versatility of ABSA methodologies. For example, Ounacer et al. [1] applied ABSA to hotel reviews, extracting actionable insights to improve services. However, this specificity highlights the need for tailored approaches that address the unique characteristics of each domain [40].

Linguistic diversity and the integration of informal user-generated content present further challenges and opportunities for ABSA. The predominance of English-language datasets in ABSA research limits its applicability to non-English contexts, where sentiment expressions vary significantly across cultures and languages [23,41,42]. Addressing this linguistic bias requires robust multilingual models capable of capturing diverse sentiment expressions [43]. Similarly, social media data, rich with consumer insights, poses challenges due to its informal language, slang, and abbreviations [44,45]. Researchers are exploring advanced natural language processing techniques to address these issues, but further work is needed to refine these methods for practical applications [46].

ABSA represents a dynamic and rapidly evolving field that increasingly leverages advanced machine learning techniques to enhance sentiment analysis. While significant progress has been made, challenges related to domain specificity, linguistic diversity, and multimodal data integration persist. Addressing these gaps through innovative methodologies and expanding ABSA's applicability to diverse languages and contexts will ensure continued advancements in the field. Such efforts will enable ABSA to provide valuable consumer insights that inform business strategies and decision-making processes, cementing its importance across various industries [47,48]. It is important to understand that some important issues, like being able to adapt to multiple languages and detecting implicit sentiment, need more in-depth research and analysis. Accordingly, the next section will examine these two gaps in detail and propose approaches to address them.

2.1. Research Gaps in ABSA: Multilingual Adaptability and Implicit Sentiment Detection

2.1.1. Multilingual Adaptability

The fact that ABSA can be used with different languages is a big research need. Despite considerable progress, most of the current ABSA research still focuses on English-language datasets [23,41,42]. This language bias makes it very hard for ABSA models to work in places where languages, attitudes, and cultural differences are very different from English. To solve problems that involve more than one language, we need to make strong cross-lingual or multilingual models. Recent transformer-based architectures, such as multilingual BERT (mBERT) and XLM-RoBERTa, have shown promise because they were trained on large multilingual corpora [9,10,17]. Using multilingual transfer learning makes it easier for a model trained in one language to work well in other languages, which means that there is no need for as many large, labeled datasets for each language. Subsequent research ought to concentrate on improving these multilingual architectures by fine-tuning, domain-specific pre-training, data augmentation and production, as well as zero-shot and few-shot learning methodologies.

2.1.2. Implicit Sentiment Detection

Finding implicit sentiment is still a major challenge in ABSA research. Explicit sentiment is expressed through specific words, but implicit sentiment requires a deeper understanding of the context and the ability to interpret it [37,38]. Implicit attitudes often depend on pragmatics, cultural circumstances, or subtle verbal cues, which are hard for modern models to pick up on. The detection of implicit sentiment can be approached using contextual embeddings and attention mechanisms, multimodal analysis, and the integration of knowledge graphs [26,33,34].

2.1.3. Practical Recommendations and Strategic Directions

Future research should focus on establishing benchmarks and standardized evaluation frameworks tailored for multilingual and implicit sentiment detection tasks, promoting collaboration among linguistic communities, and facilitating interdisciplinary partnerships [32,33].

2.2. Qualitative Contributions and Real-World Relevance of ABSA Research

2.2.1. Impact of Individual Papers

Qualitative analysis of influential papers indicates that pivotal studies often introduce novel methodologies or significant enhancements, including innovative neural network architectures or hybrid models that show considerable improvements in sentiment classification tasks [7,22,23]. Ma [5] suggested an interactive learning network that greatly improved sentiment consistency, which was a big step forward in terms of methodology. The methods that Hua et al.

[35,36] suggested, using domain adaptation and multi-feature fusion, greatly improved practical performance in several areas. This shows how important and useful these methods are in real-world situations.

2.2.2. Practical Relevance of Methodologies

The practical relevance of ABSA methodologies is evidenced by their successful applications in real-world contexts. Ounacer et al. [1] employed ABSA in the context of hotel reviews, yielding practical insights for enhancing customer experiences and informing operational decisions. ABSA's relevance in social media platforms allows businesses to accurately gauge consumer sentiments, resulting in more informed strategic marketing and customer engagement initiatives [17,38,39]. The practical implementations highlight the essential function of ABSA methodologies in converting theoretical progress into concrete advantages across diverse industries. Researchers should focus on qualitatively analyzing ABSA studies in the future by looking at how they work in the real world, how they can be used in practice, and how well new methodologies work in diverse applied situations. We can obtain a comprehensive view of ABSA's trajectory and how important it is to society and industry by using both qualitative and quantitative data.

2.3. Theoretical Integration of ABSA within NLP and Semantic Models

ABSA improves upon standard coarse-grained sentiment analysis frameworks by enabling more detailed, aspect-specific sentiment extraction. This eliminates the theoretical issues associated with polarity-based techniques. This level of detail is supported by semantic theories that stress the need to grasp the context and intricacies of language to make sense. In NLP, ABSA methods are very similar to theoretical models of how people understand language. This is especially true for transformer-based architectures that rely heavily on attention mechanisms and contextual embeddings [26,33,34]. These models help us understand language processing better by making clearer the deeper semantic relationships and contextual dependencies. Subsequent ABSA research ought to explicitly utilize and expand upon these comprehensive theoretical frameworks. This would promote dialogue across several disciplines and enhance the theoretical rigour of ABSA study. This alignment will facilitate ABSA's development as a specialist discipline and enhance the foundational concepts of sentiment analysis and NLP, resulting in more profound methodological advancements and practical applications.

3. Methodology

3.1. Data Retrieval Strategy and Conceptual Framing of ABSA Terminology

This study distinguishes itself from typical bibliometric analyses by employing a combination of conventional citation-based performance metrics and sophisticated science mapping techniques, including keyword co-occurrence networks, thematic evolution analysis, and thematic mapping. This integration enhances the analysis by identifying both mainstream and emerging niche trends. A bibliometric analysis approach was utilized for its precision in quantifying and evaluating scientific publications [9,10]. The Scopus database was chosen as the primary source for data collection due to its comprehensive content coverage and advantages over the Web of Science (WoS). Scopus offers more inclusive content, provides individual profiles for authors and institutions, and indexes a greater number of unique sources not covered by WoS. Given these advantages, the Scopus database was deemed more suitable for the analysis of ABSA research. The search process began with the development of a search string that included all documents with titles, abstracts, or keywords containing "Aspect-Based Sentiment Analysis" or "ABSA" or "Aspect-Level Sentiment Classification" or "Aspect-Sentiment Pair Extraction" or "Aspect Opinion Extraction" or "Aspect-Based Opinion Mining". These keywords were chosen for their ability to comprehensively capture the utilization of ABSA as both a concept and methodology, without being overly broad or restrictive.

The inclusion of various terms such as "Aspect-Based Sentiment Analysis" (ABSA), "Aspect-Level Sentiment Classification," "Aspect-Sentiment Pair Extraction," "Aspect Opinion Extraction," and "Aspect-Based Opinion Mining" ensures comprehensive coverage of relevant studies in this domain [11]. This approach also accounts for variations in terminology, as some studies employ alternative expressions like "Aspect-Based Opinion Mining" to describe similar methodologies [49]. While the term "aspect" in ABSA traditionally refers to specific features or attributes within textual data, in broader contexts such as customer feedback or product reviews, it can also encompass abstract elements, such as overall user experience or brand perception [14].

The initial search retrieved 2752 records from the Scopus database, primarily in the fields of computer science and engineering. To ensure results aligned with the objectives of this study, the search was refined to focus on publications in the subject areas of Computer Science, Mathematics, Engineering, Decision Sciences, and Social Sciences, spanning the years 2010 to 2024. Non-journal articles, such as conference proceedings, book chapters, and trade reports, were excluded. The retrieval of this publication database was conducted on December 09, 2024. Further exclusions were made to eliminate studies unrelated to ABSA, including studies in unrelated domains such as Veterinary, Immunology and Microbiology, Earth and Planetary Sciences, Pharmacology, Toxicology and Pharmaceutics, Agricultural and Biological Sciences, Economics, Econometrics and Finance, Energy, Medicine, Biochemistry, Genetics and Molecular

Biology, Environmental Science, Chemical Engineering, Chemistry. Articles from multidisciplinary journals, such as the Journal of Computational Linguistics, were excluded if they were not of relevance to ABSA, for example, articles that focused only on overall sentiment detection without discussing aspect-level analysis. After this refinement, 913 articles were deemed relevant and selected for detailed analysis. A flowchart outlining the data collection and refinement process is provided in Fig. 1.

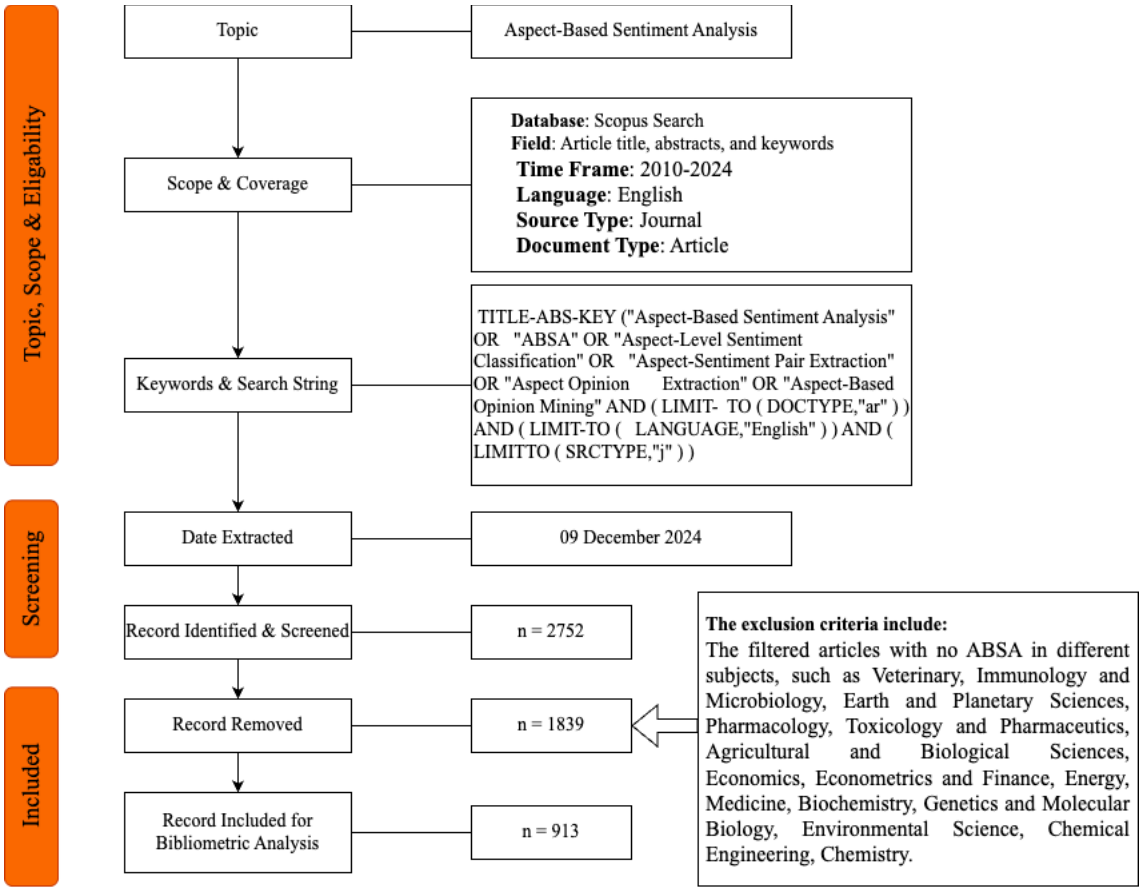


Fig. 1. The search strategy flow diagram.

3.2. Selection and Justification of Bibliometric Tools

Two major types of bibliometric software packages were used in this study for comprehensive bibliometric analysis: Harzing's Publish or Perish (PoP) and RStudio Biblioshiny. We selected PoP due to its reliability, accuracy, and adequate handling of large amounts of data based on citations from databases such as Scopus. It offers full bibliographic coverage and quality indicators such as total number of citations, citations per paper, h-index, and g-index. They are necessary for a reliable performance assessment at different hierarchical levels, such as authors, institutions, and countries. A further advantage of this tool is its capability to export citation data in RIS format, facilitating smooth interaction with other analytical tools and ensuring transparency, repeatability, and precision in bibliometric analysis. For the implementation of the tool, we chose RStudio Biblioshiny, for its capabilities in delivering advanced bibliometric visualizations and scientific mapping analyses. In comparison with other visualization tools, Biblioshiny is more flexible thanks to its advanced and customized features, such as keyword co-occurrence networks, thematic temporal analysis, and thematic mapping. The placement of this tool in the R programming environment facilitates reproducible and transparent analyses, which are important aspects of sound scientific endeavor. The availability of the tool also facilitates the adoption and replication of our methodology.

3.3. Data Analysis

The initial stage of the analysis involved a descriptive evaluation of the data to assess its quality and quantity, utilizing standard bibliometric measures [50]. The quantity dimension was measured through the total number of publications (TP), while quality was assessed using metrics such as total citations (TC), number of cited publications (NCP), average citations per publication (C/P), and average citations per cited publication (C/CP) [51]. Furthermore, advanced bibliometric indicators like the g-index (g) and h-index (h) were incorporated, as these metrics are considered more predictive of future academic achievements compared to conventional measures [52]. These indicators were

applied at various analytical levels, including country, organization, journal, and author levels [53]. Data processing and analysis were conducted using the PoP software by extracting Research Information System (RIS) data from the Scopus database.

The second stage of analysis involves visualizing the research network to examine the relationships between nodes, such as authors, affiliations, countries, citations, and keywords. In this study, the focus is on keyword co-occurrence analysis to evaluate historical, current, and emerging trends in ABSA [1]. Keywords are analyzed based on their frequency, edges (connections), and clusters, where the combination of nodes (keywords) and edges (connections) forms clusters that represent different research themes. In the visualization, larger nodes indicate higher keyword occurrence, while thicker edges indicate stronger connections between keywords. Cluster analysis groups similar keywords into clusters, allowing the identification of research interests and keyword combinations within and across clusters. This study uses RStudio Biblioshiny, an open-source software for building and visualizing bibliometric maps, to perform cluster mapping. Additionally, overlay visualizations were developed to explore the temporal evolution of ABSA research, highlighting emerging trends and future directions.

3.4. Limitations of Using Scopus as a Bibliometric Data Source

There are several limitations that should also be considered regarding the use of the Scopus database. Although comprehensive, the Scopus database might have missed some relevant publications, particularly from journals or conferences not indexed in the database. This restriction could limit the literature being searched and thus lead to the inadvertent exclusion of relevant articles. The use of Scopus indexing criteria and policies may introduce a geo- and language-bias, generally towards the publication output of certain geographical or language areas, mostly English as we can see in existing research. Therefore, some important non-English literature or region-based studies may be underrepresented, which could influence the bibliometrics and their generalizability. Finally, Scopus mainly covers peer-reviewed articles and leaves out a large amount of grey literature including technical reports, theses, dissertations, conference papers, and other nonconventional scientific articles. This restriction might inhibit the ability of the study to include new items and innovation expressed in these other genres. Subsequent studies need to integrate (or include) additional databases (i.e., the Web of Science, Google Scholar, or specific regional databases) to provide further insights and overcome some limitations. Additionally, databases may index grey literature and provide cross-referencing to further support researchers' understanding of the research environment.

4. Results and Discussion

4.1. Description of retrieved literature

This study focuses on ABSA research in various fields, published between 2010 and 2024. Review papers, conference proceedings, editorials, and other non-journal articles were excluded from the analysis, resulting in a total of 913 journal articles included. The search for these journal articles focused on English-language publications only. Collectively, these articles received 18,484 citations, with an average of 1,232 citations per year and 2 citations per article. Detailed citation metrics are presented in Table 1.

Table 1. Citation metrics.

Metrics	Data
Papers	719
Number of Citations	18,484
Years	15
Average of Citations per Year	1,232.267
Average of Citations per Paper	1.71
h-index	199
g-index	343

Table 2. Top keywords.

No	Keywords	Total Publication	Percentage
1	convolutional neural network	259	28.37%
2	semantics	220	24,10%
3	data mining	187	20,48%
4	deep learning	179	19,61%
5	syntactics	143	15,66%
6	attention mechanism	140	15,33%
7	extraction	138	15,12%
8	classification (of information)	114	12,49%
9	learning systems	114	12,49%
10	graph convolutional network	105	11,50%

Beyond ABSA as the primary keyword, the most frequently occurring keywords include “convolutional neural network” (28.37%), “semantics” (24.10%), “data mining” (20.48%), “deep learning” (19.61%), and “syntactics” (15.66%), among others, as summarized in Table 2. The prevalence of these high-frequency keywords reflects the popularity and significance of these topics within the research domain. These keywords often co-occur with ABSA, highlighting their relevance in investigating the application and potential of ABSA across diverse research areas.

4.2. Research Growth

During the initial years, research on ABSA was relatively limited, with publication numbers ranging from 7 in 2010 to a modest peak of 17 in 2015. The average citations per article during this period exhibited notable variability, reaching a high of 108 in 2010 before gradually declining in subsequent years as shown in Fig. 2. This fluctuation suggests that early studies were pioneering and highly influential, garnering substantial citations due to their foundational contributions to ABSA methodologies and applications. However, the relatively low volume of publications highlights ABSA's status as an emerging niche within sentiment analysis and natural language processing during this phase. As the field began to gain momentum, a noticeable shift occurred, marked by an increase in both the quantity and scope of research, signaling the transition to a phase of significant expansion. Between 2016 and 2020, ABSA research experienced substantial growth, with the number of publications steadily rising from 38 in 2018 to a peak of 80 in 2020. While average citations per article remained notable, they declined compared to earlier years, with figures such as 35.31 in 2017 and 36.76 in 2020. This trend indicates that the burgeoning volume of studies led to a broader distribution of citations across multiple papers. The surge in publications during this period reflects heightened interest in ABSA, driven by advancements in deep learning and the adoption of pre-trained models such as BERT. This era marked the evolution of ABSA from a niche research topic to a more established domain with practical applications in areas such as e-commerce, social media analysis, and opinion mining. Building on this foundation, the subsequent years (2021-2024) saw a dramatic increase in research output, albeit with distinct shifts in citation patterns.

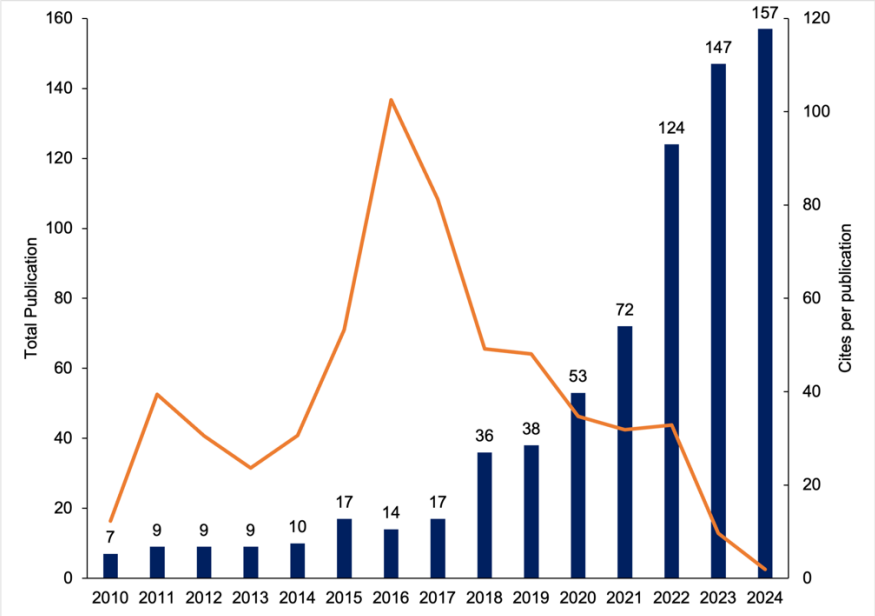


Fig. 2. Total publications and citations by year.

The most recent phase, spanning 2021 to 2024, witnessed unprecedented growth in ABSA research, culminating in 226 publications in 2024 alone. However, the average citations per article experienced a significant decline, dropping to 1.93 in 2024. This trend reflects the maturation of the field, as the influx of publications diluted the impact of individual studies. Such patterns are typical in well-established research areas where the focus shifts from groundbreaking discoveries to incremental advancements and broader applications. The lower citation rates may also be attributed to the time lag required for newer studies to accumulate citations. This phase highlights a transition in the field’s dynamics, with researchers increasingly addressing practical and domain-specific challenges. The overall trajectory of ABSA research demonstrates its evolution from an emerging field to a mature and widely adopted area of study. The early phase was characterized by high-impact foundational work, while later years have seen exponential growth in publications and diversification of applications. The decline in average citations per article in recent years suggests a pressing need for future research to prioritize innovative contributions and tackle critical challenges such as multilingual aspect extraction and domain adaptability. To sustain the field’s impact, a balance between the quantity of publications and the quality of research output will be essential.

4.3. Top Countries, Institutions, and Authors in ABSA Research

Table 3 presents the contributions of countries with more than 20 publications in the field of ABSA, providing insights into both quantity and impact. China leads in total publications (TP), with 411 articles, followed by India (163) and the United States (39). However, despite a lower volume of publications, the United States exhibits the highest citations per paper (C/P) at 28.64, indicating the substantial influence of its research contributions.

Table 3. Countries with more than 20 publications.

Country	TP	NCP	TC	C/P	C/CP	h	g
China	411	350	7835	19.06	22,39	46	71
India	163	115	1877	11,52	16,32	21	39
United States	39	33	1117	28,64	33,85	19	33
Pakistan	37	34	684	18,49	20,12	15	25
Indonesia	34	24	238	7,00	9,92	9	14
Saudi Arabia	31	24	411	13,26	17,13	9	20
Singapore	31	29	1738	56,06	59,93	18	29
Malaysia	30	25	711	23,70	28,44	9	25
Spain	27	25	801	29,67	32,04	14	25
United Kingdom	26	23	1120	43,08	48,70	15	23
Australia	21	21	328	15,62	15,62	9	17

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; and g = g-index.

In contrast, China, while being the most prolific with a C/P of 19.06, demonstrates a comparatively lower average impact per study. Notably, Singapore achieves the highest citations per cited publication (C/CP) at 56.06, reflecting the exceptional quality and influence of its relatively modest output of 31 publications. Further insights into research quality emerge from the h-index and g-index metrics. China leads in both, with an h-index of 46 and a g-index of 71, highlighting its production of both high-impact and frequently cited works. The United States and Singapore also perform strongly, with g-index values of 33 and 29, respectively, underscoring their significant contributions despite producing fewer total publications. In comparison, countries like India and Malaysia display moderate influence, with C/P values of 11.52 and 23.70, respectively, suggesting steady contributions but less citation concentration. These trends indicate that while China dominates in volume, countries such as the United States and Singapore consistently produce high-quality, impactful research. This underscores the growing diversity and specialization in ABSA research across nations, reflecting a balance between quantity and quality in advancing the field.

4.3.1. Regional Trends and Geographic Variation

In addition to publication volume and impact indicators, analyzing regional patterns of ABSA research can provide interesting contextual insights into global methodological and thematic orientations. This discussion explores regional trends and ramifications. For East Asia, including China and South Korea, the ABSA research trends are mostly related to the development of deep learning-based approaches, such as CNN and RNN. The area is a major contributor to transfer learning in ABSA, aligned with broader government-supported AI initiatives. Many ABSA projects led by Chinese organizations develop into larger programs, i.e., smart cities and intelligent commerce, indicating solid relationships between research and industry. On the other hand, in Southeast Asia, countries such as India, Pakistan, and Indonesia face scarce laboratory resources, which limits intensive training and results in work based mostly on rule-based and hybrid approaches. These regions highlight the domain-specific applications, such as ABSA in tourism, product reviews, and regional e-commerce platforms that are often customized to language and cultural diversity [1,18,23].

Western countries such as the United States, the United Kingdom, and some EU countries have put more emphasis on methodological innovation, such as: transformer models (e.g., BERT and RoBERTa) and multimodal sentiment analysis [9]. The studies show increased cross-disciplinary collaboration, especially with linguistics, the behavioral sciences, and healthcare fields. Singapore has a clearly smaller number of publications but high citations per paper. This indicates a trend towards high-quality, application-driven research, often involving benchmarking datasets and cross-domain experiments [17,33]. There are region-based differences that suggest unevenness of research infrastructure and funding as well as diversity in the practical necessity and social problems. Appreciating and exploring these regional differences is crucial to design ABSA systems that are universally applicable and discover collaborative avenues to account for methodological and contextual variations between regions.

4.3.2. Influential Contributors and Their Methodological Impact

This research attributes the large publication output to prolific authors and institutions but has not deeply examined their influence on the development of ABSA. In this respect the paper investigates the intellectual and methodological impact of several key researchers in shaping the evolution of ABSA research. The work of Ma et al. [5] is one of the research efforts that created interactive learning networks to enhance sentiment coherence in ABSA. His work

addresses the high topicality of the problem of contextual coherence, which increased due to applications containing opinions across multiple aspects. Y. Ma et al. introduced a model that aggregates various elements to better perform sentiment analysis in diverse domains. Such innovation contributes to the transferability and robustness in ABSA applications, which are two important issues in practical scenarios. S. Ounacer et al. [1] demonstrated the applied impact of ABSA on analysis of hospitality services, showing its progression from theoretical nature through industry-customized measures. Their approach design has provided a roadmap for studies of service quality and customer experience. Furthermore, hybrid models which combined grammar rules with deep learning methods have been studied by Suhariyanto and Abdullah [18,23]. Their work made it easier to discover concealed features, and led to the development of ABSA systems that can understand language better, especially for under-resourced languages and cultures. The continued legacy of these authors is observed by the trend of themes such as contextual modeling, transformer-based architectures, and application-specific ABSA systems. It provides a foundation for further research, influencing both the theoretical and practical perspectives of ABSA.

Table 4. Institutions with more than 10 publications.

Institution	Country	TP	NCP	TC	C/P	C/CP	h	g
Ministry of Education of the People's Republic of China	China	23	21	331	14.39	15,76	11	18
Nanyang Technological University	Singapore	22	20	1523	69,23	76,15	15	20
South China Normal University	China	19	16	213	11,21	13,31	7	14
Shandong Normal University	China	17	13	266	15,65	20,46	9	13
Wuhan University	China	17	14	176	10,35	12,57	7	13
Chinese Academy of Sciences	China	16	15	450	28,13	30,00	12	15
Harbin Institute of Technology	China	16	12	612	38,25	51,00	8	12
Tsinghua University	China	15	12	542	36,13	45,17	10	12
School of Computer Science and Engineering	Australia	12	11	1017	85,75	92,45	9	11
Xinjiang University	China	11	9	136	12,36	15,11	5	9
Xi'an Jiaotong University	China	11	11	254	23,09	23,09	10	11

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; and g = g-index.

Table 4 presents the contributions of institutions with more than 10 publications in the field of ABSA, providing insights into their research output and impact. Leading the list is the Ministry of Education of the People's Republic of China, with 23 total publications (TP) and 21 citation papers (NCP), resulting in 331 total citations (TC). Despite a relatively modest average citations per paper (C/P) of 14.39, the institution demonstrates consistent research productivity and influence, as reflected in its h-index of 11 and g-index of 18. In contrast, Nanyang Technological University (Singapore) achieves significantly higher impact metrics, with a C/P of 69.23 and a citation per citation paper (C/CP) of 76.15, based on 22 publications. Its high total citation count (1,523 TC) and strong h-index (15) and g-index (20) emphasize its pivotal role in producing high-quality, impactful research in the ABSA domain. Other prominent contributors include the Harbin Institute of Technology (China) and the School of Computer Science and Engineering (Australia). The Harbin Institute of Technology, with 16 publications, boasts a C/P of 38.25 and a C/CP of 51.00, reflecting the significant depth and influence of its research. Similarly, the School of Computer Science and

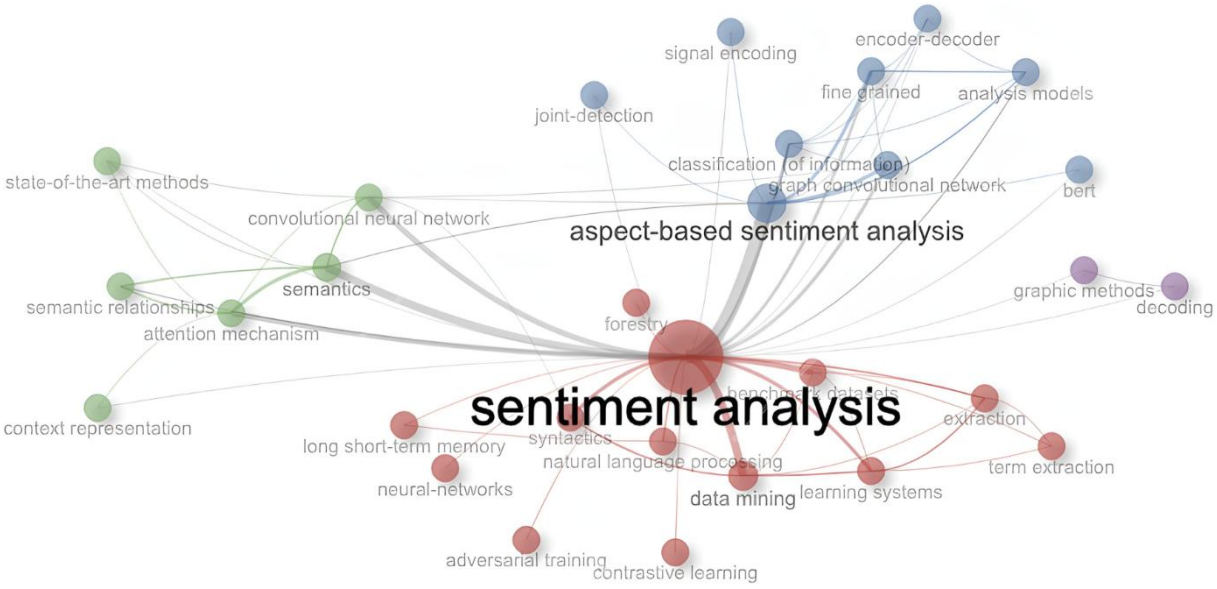


Fig. 3. Co-occurrence network of the Ministry of Education of the People's Republic of China.

Engineering, with 12 publications, demonstrates exceptional impact, achieving a C/P of 85.75 and a C/CP of 92.45. This underscores its capability to produce highly cited, influential work despite a smaller research output. The findings reveal that while Chinese institutions dominate in terms of total publication volume, institutions like Nanyang Technological University and the School of Computer Science and Engineering excel in research quality and citation impact. These patterns reflect the global and diverse nature of ABSA research, emphasizing the importance of fostering collaboration among high-impact institutions to drive innovation and advance the field further.

The co-occurrence network analysis for the Ministry of Education of the People's Republic of China shown at Fig. 3 identifies "sentiment analysis" as the central keyword, with strong associations to related terms such as "aspect-based sentiment analysis," "data mining," and "convolutional neural networks." This pattern indicates a research focus on integrating fundamental sentiment analysis methodologies with advanced machine learning and neural network applications. Secondary keywords, including "semantic relationships," "attention mechanisms," and "fine-grained analysis," underscore the institution's emphasis on enhancing the granularity and semantic precision of sentiment analysis models. The diversity of interconnected keywords reflects a comprehensive approach, incorporating methodological innovations (e.g., "state-of-the-art methods") alongside broader applications in natural language processing.

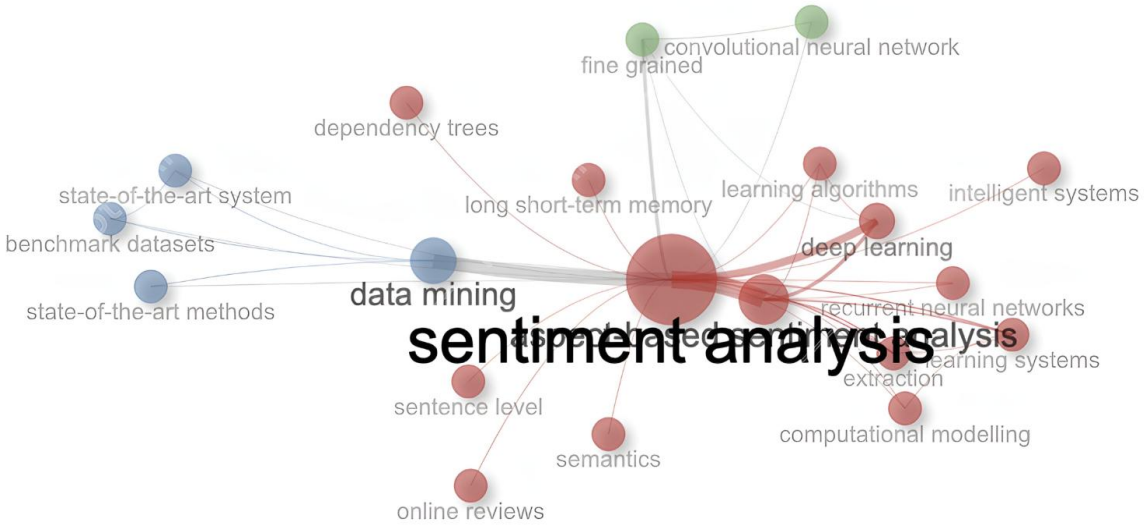


Fig. 4. Co-occurrence network of Nanyang Technological University.

The co-occurrence network for Nanyang Technological University also places “sentiment analysis” at the center but with a targeted research sub-area, shown in Fig. 4. The highlighting of “deep learning”, “intelligent systems”, and “learning algorithms” indicates a pervasive focus on the use of state-of-the-art machine learning for improving ABSA models. “Online” and “benchmark”, together with “reviews” and “datasets”, highlight the institution’s practical applications, as well as its model-evaluation through standardized datasets. The topic-theme network of Nanyang Technological University (Table 4) shows that it has more concentrated research topics than the Ministry of Education of China, particularly focused on advanced learning systems and the applications of learning systems in intelligent systems. Comparison of the two institutions reveals different but complementary research directions. The Department of Education of China adopts a complete and basic method, paying attention to methods and meanings. Nanyang Technological University conducts focused, applied research, particularly in the areas of advanced learning systems, and their practical deployment. Both are key to stimulate ABSA research, whereby their different foci highlight the relationship between basic research and applied innovation. Such an analysis underscores the importance of institutional collaboration in connecting theoretical development with practical applications that are significant, and therefore helps the field progress.

4.4. Trend Topics in ABSA Research

The trend levels graph demonstrates research focus development in ABSA from 2010 to 2024 by focusing on the development of the key terms based on the results in Fig. 5. Initially, there were hot issues like “product aspect,” “conditional random field,” and “aspect-level” appearing as the focus in ABSA research, indicating that researchers were attempting to devise the concept of ABSA and forge its backbone methodologies. In 2015, with the appearance of the themes "text processing" and "aspect identification" we can observe a growing interest in improving techniques (from a learning algorithms point of view) for deriving action realizations from text data. During this time, most of the research focused on rule-based and statistical methods to identify aspects and classify sentiment. Only after 2017 did research move towards advanced machine learning methods, as indicated by an increase in the terms “neural networks”, “data mining”, and “long short-term memory”. This turning point came with the adoption of deep learning, which

enabled the building of better models that can handle long sequences of data and learn intricate patterns inside textual data.

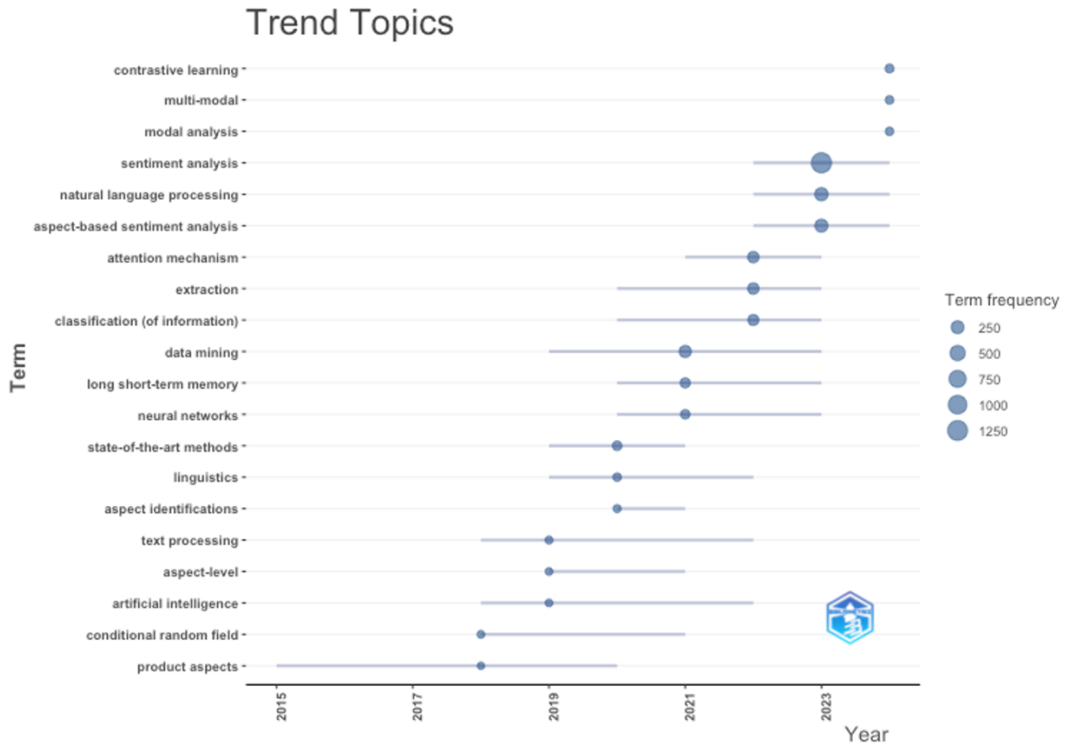


Fig. 5. Trend topics in ABSA research between 2010 and 2024.

4.4.1. Basic Topics (2010-2014): Product Aspects and Rule-Based Approaches

During this early period, research in ABSA centered on identifying explicit product features using rule-based and probabilistic models. Key topics such as product aspects, conditional random field, and aspect-level classification highlight efforts to establish the fundamental architecture of ABSA systems. Conditional Random Fields (CRFs) were widely adopted to capture sequential dependencies and extract aspect-sentiment pairs, laying the groundwork for aspect-level granularity in sentiment modeling.

4.4.2. Transition to Textual Enhancement and Aspect Identification (2015-2017)

Subsequent years marked a refinement in textual representation and aspect identification. Topics such as text processing, aspect identification, and aspect-level sentiment classification gained traction, reflecting a shift towards improving preprocessing pipelines and capturing nuanced sentiment expressions. During this phase, tokenization, part-of-speech tagging, and dependency parsing became standard for enhancing aspect and sentiment extraction accuracy.

4.4.3. The Emergence of Deep Learning and Neural Modeling (2017-2020)

The period between 2017 and 2020 witnessed the emergence of deep learning as a dominant methodology in ABSA. Terms such as neural networks, long short-term memory (LSTM), data mining, and state-of-the-art methods indicate a paradigm shift. These architectures facilitated the modeling of complex semantic patterns in text and enabled scalable solutions across large datasets. Moreover, data mining approaches were increasingly used for opinion aggregation and knowledge discovery from user-generated content across e-commerce and social platforms.

4.4.4. AI Integration and Transfer Learning (2020-2022)

Rapid advancement in AI research during this period propelled ABSA into broader AI ecosystems. The emergence of topics such as attention mechanisms, extraction, and classification (of information) highlights a growing emphasis on model interpretability and precision. Transformer-based models like BERT brought significant improvements in capturing contextual dependencies, enabling aspect-aware sentiment modeling with greater depth. These models also facilitated cross-domain and cross-lingual applications through transfer learning.

4.4.5. Recent and Emerging Trends (2022-2024): Multimodal and Contrastive Learning

The most recent phase signals an expansion of ABSA beyond traditional text analysis. Topics such as multimodal, modal analysis, and contrastive learning reflect the integration of visual, textual, and auditory modalities to enhance sentiment interpretation. These techniques aim to increase the robustness and context-awareness of ABSA systems. Meanwhile, core topics such as sentiment analysis and aspect-based sentiment analysis maintain the highest frequency, reaffirming their foundational relevance. The continued rise of attention mechanisms, benchmark datasets, and fine-grained analysis suggests a focus on building high-performance and generalizable ABSA models.

Simultaneously, terms such as "state-of-the-art methods", "artificial intelligence" and "natural language processing" are becoming increasingly important, suggesting that ABSA has been put into the context of a more general AI framework. In 2021, several emerging topics including “multi-modal,” “contrastive learning” and “modal analysis” have shown accomplishments in learning from multiple tasks, and in analyzing the sentiments from different data modalities such as text, images, and audio for better understanding of sentiment. The results show impressive progress in ABSA study, but the issues in multilingual aspect extraction, implicit sentiment detection, and domain generalization remain. The response to these challenges can be found in the potential exploitation of advanced techniques such as contrastive learning and multi-modal analysis. The increasing usage of such phrases as “attention mechanism” and “encoder-decoder” reflects that there is a heavy reliance on transformer-based models including BERT and GPT to improve ABSA. The development of the discipline is marked by a continuing focus on fine-grained sentiment analysis, including aspect-based sentiment analysis, to deliver more in-depth and actionable insights for e-commerce, healthcare, and social media applications.

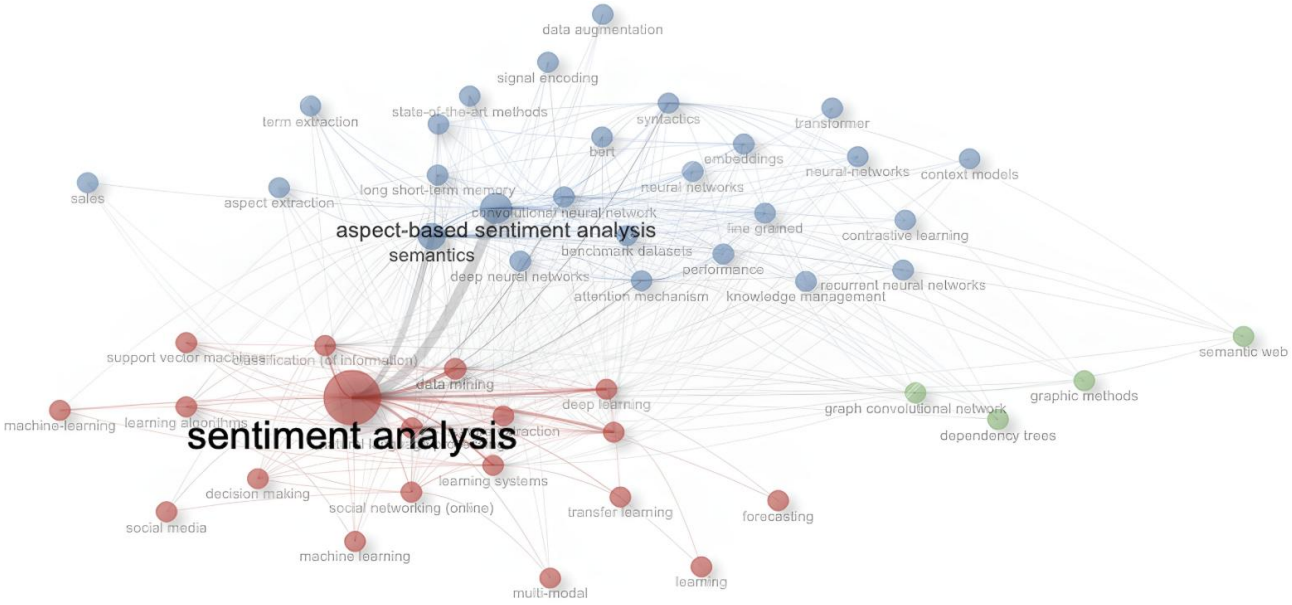


Fig. 6. Co-occurrence network in ABSA.

Fig. 6 depicts the co-occurrence network and provides a thorough knowledge into the dynamics of the keywords in ABSA studies from 2010 to 2024. Sentiment analysis is pivotal in such a network as a fundamental bridge keyword that ties several sub-fields together. Additionally, words like aspect-based sentiment analysis, data mining, and neural networks form parts of ABSA research. Terms such as “transformer”, “BERT”, and “attention mechanism” appear frequently within the research literature, suggesting that more advanced deep learning methods and transformer-based architectures are increasingly being integrated with the aim of improving both efficiency and effectiveness of ABSA models. There are also the terms "state-of-the-art methods," "benchmark datasets," and "fine-grained analysis," which highlight the importance of improving model evaluation and analysis and further bridge the gap between the theoretical and practical aspects of the discipline. The network suggests important opportunities and challenges in ABSA research. "Semantic relationships," "aspect extraction," and "classification of information" are expressions that reflect current efforts to increase the precision of sentiment extraction and aspect classification. Challenging problems such as multilingual processing, and domain generalization, remain as important areas for future research. Novel, under-represented paradigms such as "multi-modal" and "transfer learning" would indicate the way forward for addition of multiple data modalities (such as text, image, and audio) as well as application of transfer learning to enhance the performance in different languages and domains. The co-occurrence network reinforces the trend of the field towards more complex techniques. Further developments will likely focus on expanding the targets and use cases of ABSA, handling language- and domain-specific issues, and building scalable, adaptive models for deployment in the broader

real world. This path provides a glimpse of the dynamic and evolving nature of ABSA research, demonstrating opportunities for novelty and interdisciplinary partnerships.

4.5. Challenges and Future Directions of ABSA Research

ABSA has evolved considerably, from initial examination focusing on aspects and sentiment categorization to more sophisticated techniques such as deep learning and transformer-based architectures. Despite these advances, the field continues to face many open issues, including language ambiguity, implicit sentiment recognition, and the development of robust models capable of generalizing well across different domains and languages. To address these challenges, we must further investigate new techniques, such as transfer learning and multimodal approaches, and add contextual and cultural information to social media sentiment analysis models. This section discusses the challenges in ABSA research, and its main objectives are to outline the future directions to overcome those challenges, benefiting the development of more accurate, scalable, and general ABSA solutions.

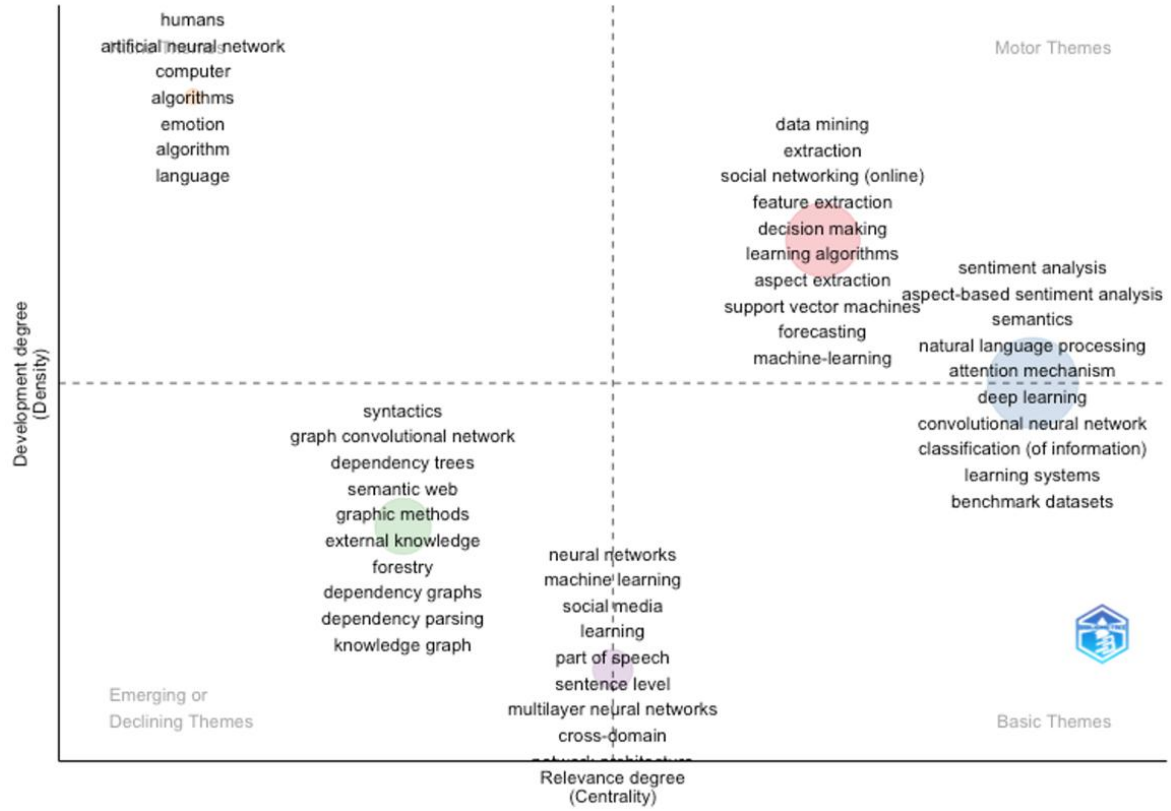


Fig. 7. Thematic maps in ABSA.

Fig. 7. Layout of research topics of ABSA from 2010 to 2024, divided into four quadrants: Basic Themes, Motor Themes, Niche Themes, and Emerging or Declining Themes. The Basic Themes quadrant consists of high-relevance (centrality) and moderate-development (density) topics such as: “sentiment analysis,” “aspect-based sentiment analysis,” “deep learning,” and “natural language processing.” The nine ABCPAs principles underpin ABSA research and are used as the core methods and tools that can be deployed in many fields. This quadrant also highlights existing difficulties, such as the development of scalable systems that can handle multilingual data and uncover implicit sentiment. An emphasis on the importance of benchmarked datasets is provided by this quadrant, which further underscores the need for commonly accepted evaluation metrics for better model precision and consistency. The Motor Themes quadrant contains high-relevance and high-development topics, comprising data mining, aspect extraction, learning algorithms, and decision making. These themes represent more developed, advanced areas that are vital to drive innovation in ABSA. Their focus on obtaining meaningful insights from textual data and exploiting these insights in real-world decision-making contexts, such as customer experience analysis or automated systems, has made them practical and valuable. To further advance future investigations in this line of work, enhancing feature extraction methods and model interpretability should be developed while challenging issues that are domain-specific need to be addressed. The development of advanced models, for example, transformer-based approaches and multimodal learning, provides room for improved performance and generality for ABSA.

The Niche Themes quadrant includes highly specialized but less interconnected topics, such as "artificial neural network," "emotion," and "language." While these themes are less central to the broader ABSA field, they offer

significant potential for deep exploration in specific applications, such as emotion detection and cultural sentiment analysis. Conversely, the Emerging or Declining Themes quadrant features topics with lower development and relevance, including "dependency parsing," "semantic web," and "graph convolutional networks." Although these themes are currently underexplored, they hold promise for innovation. For example, employing "knowledge graphs" and "graph convolutional networks" could enhance relational sentiment analysis by effectively capturing the relationships between entities and their attributes. Addressing the challenges within these quadrants will require interdisciplinary collaboration and the application of novel methodologies. By focusing on the refinement of foundational themes, leveraging advancements in motor themes, and exploring the potential of niche and emerging themes, ABSA research can achieve greater scalability, flexibility, and applicability across diverse real-world contexts.

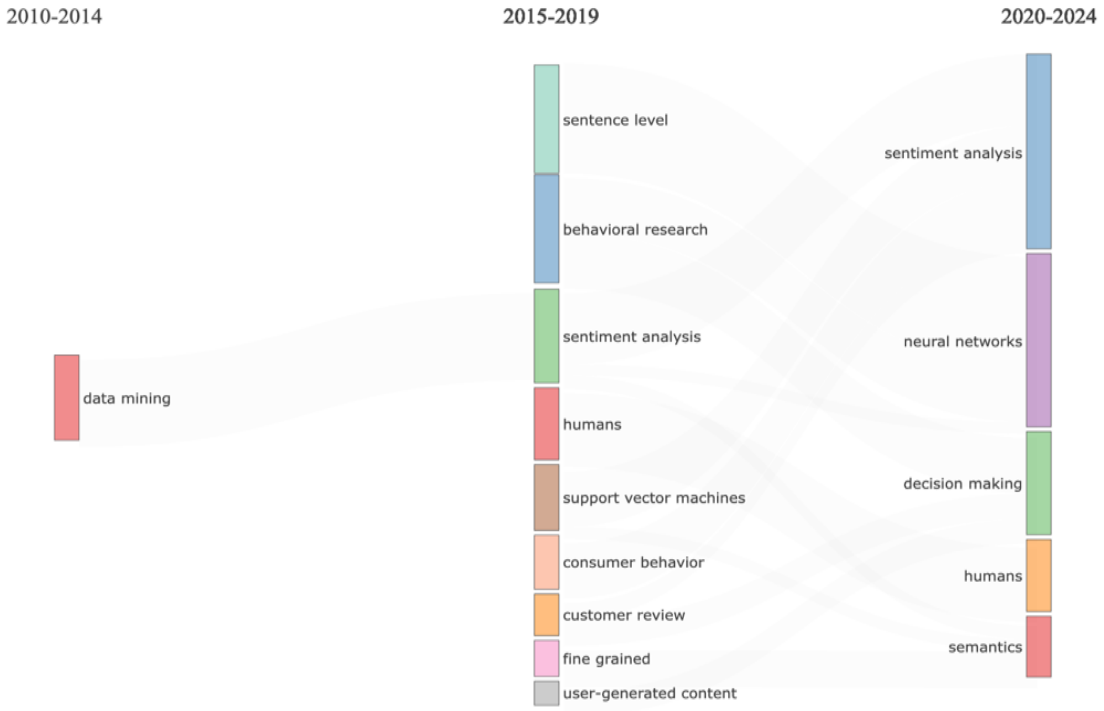


Fig. 8. Thematic evolution in ABSA.

This comprehensive thematic evolution analysis represents a novel contribution to the field by elucidating the transitions among the foundational, transitional, and contemporary phases of ABSA research, a topic inadequately addressed in prior bibliometric studies. Fig. 8 captures the progression of research themes in ABSA over three distinct periods: 2010-2014, 2015-2019, and 2020-2024. The 2010-2014 period is characterized by a strong focus on "data mining," which served as the foundation for extracting meaningful insights from textual data as shown in Fig. 8. This phase represents the early exploration of ABSA, with researchers primarily developing methods for identifying and classifying sentiment patterns within unstructured datasets. The emphasis on "data mining" reflects the reliance on statistical and basic computational techniques, marking the initial steps in ABSA's development. The 2015-2019 period saw a diversification of research themes, with the emergence of topics such as "sentence level," "behavioral research," "sentiment analysis," "support vector machines," and "fine-grained" analysis. During this phase, the field shifted toward more nuanced and application-driven research, focusing on granular sentiment analysis at the sentence level and consumer-specific behavior. The presence of "support vector machines" highlights the adoption of machine learning algorithms to enhance the accuracy of aspect extraction and sentiment classification. Themes like "consumer behavior" and "customer review" illustrate ABSA's growing relevance in practical applications, particularly in domains such as e-commerce and social media, where customer sentiment plays a pivotal role.

In the 2020-2024 period, themes such as "neural networks," "decision making," and "semantics" have emerged, reflecting the widespread integration of advanced deep learning techniques into ABSA research. The prominence of "neural networks" underscores the adoption of transformer-based architectures, including models like BERT and GPT, to tackle complex challenges such as implicit sentiment detection and domain generalization. The persistent presence of "humans" across all periods signifies a continued focus on user-centric analysis, while the rise of "semantics" highlights the growing emphasis on understanding contextual relationships and linguistic subtleties in ABSA tasks. This thematic evolution illustrates a clear trajectory from foundational methodologies to sophisticated, context-aware approaches. Future research opportunities lie in extending ABSA to multilingual and multimodal domains, addressing scalability challenges, and enhancing interpretability to support real-world applications. The progression underscores the field's dynamic nature and its alignment with advancements in artificial intelligence and natural language processing.

4.6. Emerging Paradigms in ABSA and Their Methodological Implications

The integration of multimodal data sources, such as images and audio alongside text, represents a promising direction for understanding user sentiment. This approach has disruptive potential in domains like marketing, social media analytics and human–computer interaction, as it allows for improved sentiment detection and analysis [17,38,39]. Contrastive learning methods can be introduced to improve ABSA models when encoding the sentiment feature representations even for small-scale differences in sentiment. Advancement in this respect has strong implications for high-stakes areas such as finance and healthcare, where very accurate sentiment analysis is a crucial factor for decision-making processes [26,33,34]. Independent and joint modeling of multiple modes can provide us with better insight into expression patterns of sentiment across different contexts. This is a key paradigm for developing adaptive ABSA systems that deliver context dependent analysis. The in-depth scrutiny of these new topics and the understanding of their generalization will have a deep impact on future research in ABSA, influencing methodological developments, stimulating interdisciplinary cooperation and innovation in many practical applications and industrial sectors.

4.7. Cross-Sectoral Applications and Industrial Relevance of ABSA Research

The application of ABSA techniques in e-commerce is beneficial to better understand consumer preferences and attitudes, leading to increased customer satisfaction, enhanced market focus, and product innovation [1,17]. Enterprises can use ABSA to extract product reviews for analysis, improve products based on new requirements in a timely manner, and capture a market advantage. In healthcare, ABSA can be applied to analyze patient comments from all forms of media as well as social media data to gain an understanding of patient experiences, satisfaction and perceptions of healthcare services or products. It enables providers and policy makers to make evidence-based decisions that will lead to improved quality of care, greater patient involvement and successful healthcare delivery [38,39]. ABSA provides rich coverage of political campaigns, policy issues, and public opinion. Politicians and campaign strategists use ABSA to understand voter mood, identify issues of importance and tailor their messages and policies to better match public demands, leading to more effective political communication and engagement [35,36]. The correlation between ABSA research trends and their practical applications illustrates the significance of continuous advancement in ABSA methods.

5. Conclusion

This study is a review of ABSA research from 2010 to 2024, based on performance indicators, such as h-index, g-index, and citations, keywords, themes, and trends. The results reveal a shift from rule-based and statistical approaches to deep learning and transformer architectures. Emerging directions, including multimodal ABSA, contrastive learning, and domain generalization, demonstrate significant potential yet encounter persistent challenges related to multilingual coverage, implicit sentiment detection, and scalability. Future models must be interpretable, adaptable across domains, and deployable in real-world settings, utilizing techniques such as transfer learning to address these challenges. This study proposes a strategic framework to advance ABSA as both a robust theoretical discipline and a scalable practical tool across diverse industries. This study combines performance measures and science mapping into one framework, while also revealing interesting topics that have not been fully explored, such as multilingual and multimodal ABSA. Consequently, it provides a framework for scholars and practical guidance for practitioners.

All the Declarations and Statements

Author Contributions Statement

Muhammad Resa Arif Yudianto – Conceptualization, Methodology, Data Curation, Formal Analysis, Visualization, and Writing – Original Draft: Developed the research concept and methodological framework; collected, processed, and analyzed the bibliographic data; interpreted the findings; prepared the visualizations; and drafted the manuscript.
Handaru Jati – Supervision, Validation, and Writing – Review and Editing: Supervised the research process, validated the methodology and interpretation of the findings, and critically reviewed and revised the manuscript.
Fatchul Arifin – Supervision, Validation, and Writing - Review and Editing: Provided academic supervision, validated the research design and findings, and critically reviewed and improved the manuscript.

All authors have read and agreed to the published version of the manuscript.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

Funding Declaration

None.

Data Availability Statement

The bibliographic metadata analyzed in this study were retrieved from the Scopus database on December 9, 2024. Access to the raw records is subject to Scopus licensing and subscription terms. The processed data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable licensing restrictions.

Ethical Declarations

None.

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Declaration of Generative AI in Scholarly Writing

During the preparation and revision of this manuscript, the authors used generative AI-assisted tools solely to improve language clarity, grammar, readability, and editorial consistency. All AI-assisted output was carefully reviewed, verified, and edited by the authors, who take full responsibility for the final manuscript. Generative AI was not used to collect or manipulate the bibliographic data, conduct the bibliometric analysis, generate the reported results, or independently formulate the findings and conclusions.

Abbreviations

The following abbreviations are used in this manuscript:

ABSA – Aspect-Based Sentiment Analysis
AI – Artificial Intelligence
NLP – Natural Language Processing
CNN – Convolutional Neural Network
RNN – Recurrent Neural Network
LSTM – Long Short-Term Memory
CRF – Conditional Random Field
BERT – Bidirectional Encoder Representations from Transformers
mBERT – multilingual Bidirectional Encoder Representations from Transformers
XLM-RoBERTa – Cross-lingual Language Model-RoBERTa
GPT – Generative Pre-trained Transformer
WoS – Web of Science
PoP – Publish or Perish
RIS – Research Information Systems
TP – Total Number of Publications
NCP – Number of Cited Publications
TC – Total Citations
C/P – Average Citations per Publication
C/CP – Average Citations per Cited Publication

Appendix

None.

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