East Asian Journal of Multidisciplinary Research (EAJMR)
Vol. 5, No. 8, 2026: 3519 - 3534

Optimization of Machine Learning–Based Recommendation Systems on E-Commerce Platforms

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A R T I C L E I N F O

Keywords: Machine Learning, Recommendation Systems, E-Commerce.

Received : 13, June
Revised : 20, July
Accepted: 31, August

A B S T R A C T

This study aims to analyze optimization strategies for machine learning–based recommendation systems in e-commerce environments, identify commonly applied algorithms, and examine emerging opportunities and implementation challenges. A Systematic Literature Review (SLR) was conducted following the PRISMA 2020 framework. Literature was collected from six major academic databases, covering publications from 2020 to 2025. From an initial pool of 286 records, 10 studies met the eligibility criteria and were included in the final analysis. The findings indicate that deep learning, hybrid recommendation models, sequential recommendation approaches, and large language model–based systems significantly enhance recommendation accuracy and personalization. User behavior analytics emerged as a critical factor in adaptive recommendation systems, while conversational AI and multimodal technologies represent promising future directions. Despite these advancements, issues related to scalability, explainability, fairness, and privacy remain significant challenges requiring further research and optimization.

DOI prefix: https://doi.org/10.55927/eajmr.v5i8.284
ISSN-E: 2828 – 1519 (Online)
https://journaleajmr.my.id/index.php/eajmr

INTRODUCTION

The rapid advancement of digital technologies has significantly transformed the global commerce landscape through the exponential growth of e-commerce platforms that connect millions of consumers with vast product catalogs in real time. In such information-rich environments, consumers frequently experience information overload, making it increasingly difficult to identify products that align with their preferences and purchasing needs (Roy & Dutta, 2022; Castells & Jannach, 2023). This challenge has encouraged e-commerce companies to implement recommendation systems as effective information-filtering mechanisms that enhance user experience and improve product discovery efficiency (Karimova, 2016; Felfernig et al., 2024). Recommendation systems have become a fundamental component of modern e-commerce platforms because they facilitate faster and more accurate purchasing decisions through data-driven personalization (Raza et al., 2025; Rajpoot et al., 2026). Furthermore, these systems contribute significantly to customer retention, user engagement, and revenue growth by presenting highly relevant product suggestions to individual consumers (Roy & Dutta, 2022; Syamsuri et al., 2025).

The development of artificial intelligence and machine learning has revolutionized the design and performance of recommendation systems. Traditional approaches based on collaborative filtering and content-based filtering have evolved into more sophisticated models incorporating matrix factorization, deep learning, graph neural networks, and transformer-based architectures (Portugal et al., 2018; Raza et al., 2025). Machine learning algorithms enable recommendation systems to learn from users' browsing histories, purchase records, reviews, ratings, and behavioral interactions, thereby generating highly personalized recommendations (Makhmudov, 2025; Poniszewska-Maranda et al., 2025). Such capabilities allow recommendation systems to adapt dynamically to changing consumer preferences and market trends, enhancing both recommendation accuracy and customer satisfaction (Roy & Dutta, 2022; Rajpoot et al., 2026). Consequently, machine learning has emerged as a critical technological foundation for next-generation e-commerce recommendation systems (Castells & Jannach, 2023; Raza et al., 2025).

Despite substantial progress, optimizing machine learning–based recommendation systems remains a complex challenge. Issues such as data sparsity, cold-start problems, scalability limitations, long-tail product recommendations, and rapidly evolving consumer behaviors continue to hinder recommendation performance (Roy & Dutta, 2022; Salunke & Nichite, 2022). The increasing volume and velocity of user-generated data further require recommendation systems to process large-scale datasets efficiently while maintaining high prediction quality and real-time responsiveness (Ezeife & Karlapalepu, 2023; Rajpoot et al., 2026). Moreover, organizations must balance personalization effectiveness with concerns regarding user privacy, algorithmic transparency, fairness, and ethical data utilization (Felfernig et al., 2024; Raza et al., 2025). These challenges highlight the necessity of continuous optimization to ensure that recommendation systems remain effective and trustworthy in dynamic e-commerce environments.

Recent studies have focused on integrating advanced machine learning techniques to enhance recommendation quality and overcome the limitations of conventional approaches. Hybrid recommendation models that combine collaborative filtering, content-based filtering, and deep learning methods have demonstrated superior performance compared to single-method approaches (Tahir et al., 2025; Makhmudov, 2025). Additionally, emerging technologies such as large language models, conversational recommender systems, reinforcement learning, and multimodal recommendation frameworks have opened new opportunities for developing more intelligent, context-aware, and interactive recommendation systems (Rajpoot et al., 2026; Raza et al., 2025). These technological advancements indicate that recommendation system optimization remains a highly relevant and rapidly evolving research domain with substantial implications for e-commerce competitiveness and innovation.

The urgency of this research stems from the growing dependence of e-commerce platforms on recommendation systems to improve customer engagement, conversion rates, and long-term customer retention. Poorly optimized recommendation systems may reduce recommendation relevance, negatively affect user satisfaction, and ultimately decrease sales opportunities and organizational profitability (Syamsuri et al., 2025; Roy & Dutta, 2022). Simultaneously, the rapid evolution of machine learning technologies requires continuous assessment and optimization of recommendation algorithms to ensure their effectiveness in meeting increasingly diverse consumer demands (Poniszewska-Maranda et al., 2025; Rajpoot et al., 2026). Therefore, investigating optimization strategies for machine learning–based recommendation systems has become essential for sustaining the competitiveness and growth of modern e-commerce platforms.

Several previous studies have examined recommendation systems from different perspectives. Roy and Dutta (2022) conducted a systematic review of recommender systems and identified key challenges and future research directions. Portugal et al. (2018) analyzed the application of machine learning algorithms in recommendation systems and concluded that machine learning significantly improves prediction performance. Ezeife and Karlapalepu (2023) emphasized the importance of utilizing sequential user behavior patterns to enhance recommendation accuracy in e-commerce environments. Meanwhile, Rajpoot et al. (2026) highlighted the transformative potential of deep learning, large language models, and conversational recommender systems in shaping future recommendation technologies. Although these studies provide valuable insights, there remains a need for a comprehensive investigation specifically focused on optimization strategies for machine learning–based recommendation systems in e-commerce platforms, considering emerging technologies and current implementation challenges.

Based on the aforementioned background, this study aims to analyze and identify optimization strategies for machine learning–based recommendation systems on e-commerce platforms, evaluate the effectiveness of various recommendation algorithms, and examine the challenges and opportunities associated with their implementation. Furthermore, the study seeks to provide

insights into how optimized recommendation systems can improve recommendation accuracy, service personalization, user satisfaction, and overall business performance within the e-commerce ecosystem.

THEORETICAL REVIEW

Machine Learning-Based Recommendation Systems

Recommendation systems are widely used in e-commerce to provide personalized product suggestions based on user preferences and behavioral data. Traditional approaches mainly rely on collaborative filtering and content-based filtering, while recent developments increasingly incorporate machine learning and deep learning techniques to improve recommendation accuracy and personalization. These advanced approaches enable systems to identify complex relationships between users and products and adapt to changing consumer preferences (Roy & Dutta, 2022; Raza et al., 2025).

Optimization of Recommendation Systems

The optimization of recommendation systems aims to improve prediction accuracy, personalization, and system performance while addressing common challenges such as data sparsity, cold-start problems, and scalability. Hybrid recommendation models combine multiple approaches, including collaborative filtering, content-based filtering, and deep learning, to overcome the limitations of individual methods. User behavior data, such as browsing history, purchases, ratings, and interactions, also play an important role in developing adaptive and context-aware recommendations (Makhmudov, 2025; Poniszewska-Maranda et al., 2025).

Emerging Technologies in Recommendation Systems

Recent developments have expanded recommendation systems through the integration of large language models (LLMs), conversational AI, and multimodal technologies. These approaches enable recommendation systems to better understand user intentions, contextual information, and multiple forms of interaction. However, their implementation continues to face challenges related to scalability, privacy, explainability, fairness, and computational efficiency (Felfernig et al., 2024; Raza et al., 2025; Rajpoot et al., 2026).

METHODOLOGY

This study employed a Systematic Literature Review (SLR) approach to comprehensively investigate the optimization of machine learning–based recommendation systems on e-commerce platforms. The SLR method was selected because it provides a structured, transparent, and replicable procedure for identifying, evaluating, and synthesizing existing scientific evidence related to a particular research topic. Through this approach, researchers can systematically map current developments, identify research gaps, and formulate future research directions based on accumulated scholarly findings (Kitchenham & Charters, 2007; Snyder, 2019). The review process was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses

(PRISMA 2020) framework to ensure methodological rigor and transparency throughout the study selection process (Page et al., 2021).

The review process began with the formulation of three research questions: (1) What machine learning algorithms are commonly applied in e-commerce recommendation systems? (2) What optimization strategies have been proposed to improve recommendation performance? and (3) What challenges and future opportunities are associated with the implementation of machine learning–based recommendation systems in e-commerce environments? These questions guided the search strategy, study selection, data extraction, and thematic synthesis stages (Xiao & Watson, 2019).

A comprehensive literature search was conducted using six major academic databases, namely Scopus, ScienceDirect, SpringerLink, IEEE Xplore, ACM Digital Library, and Google Scholar. The search process utilized combinations of keywords such as *"machine learning," "recommendation system," "recommender system," "e-commerce," "recommendation optimization," "deep learning recommendation,"* and *"personalized recommendation."* Boolean operators (AND and OR) were employed to refine search results and ensure broad coverage of relevant studies. The search was restricted to publications published between 2020 and 2025, allowing the review to capture the most recent developments in recommendation system technologies and machine learning applications.

Following the identification stage, a total of 286 records were retrieved from the selected databases. Specifically, 74 articles were identified from Scopus, 61 from ScienceDirect, 42 from SpringerLink, 35 from IEEE Xplore, 28 from ACM Digital Library, and 46 from Google Scholar. All retrieved records were exported and compiled into a reference management system for further screening. During the duplicate removal process, 45 duplicate articles were identified and excluded, leaving 241 unique records for further evaluation.

The screening stage involved examining the titles, abstracts, and keywords of the 241 remaining articles. At this stage, 189 articles were excluded because they did not directly address recommendation systems in e-commerce environments, focused on unrelated artificial intelligence applications, discussed recommendation systems in domains other than e-commerce (such as healthcare, education, or entertainment), or lacked a machine learning perspective. Consequently, 52 articles were retained for full-text assessment.

The eligibility assessment involved a detailed examination of the full texts of these 52 articles. Each study was evaluated against predefined inclusion and exclusion criteria. The inclusion criteria consisted of: (1) peer-reviewed journal articles or international conference proceedings; (2) studies focusing on the implementation, development, evaluation, or optimization of machine learning–based recommendation systems within e-commerce platforms; (3) availability of full-text access; and (4) publication in English. Conversely, studies were excluded if they were editorials, review notes, opinion papers, book chapters, duplicated publications, or lacked sufficient methodological and empirical evidence. During this phase, 42 articles were excluded for various reasons, including insufficient discussion of optimization techniques, lack of empirical evaluation, focus on

general recommendation systems without an e-commerce context, or inadequate methodological transparency.

As a result of the PRISMA selection process, 10 articles met all eligibility requirements and were included in the final review. These studies represented the most relevant and methodologically robust literature addressing machine learning–based recommendation systems in e-commerce environments. The selected articles formed the basis for data extraction and subsequent thematic analysis.

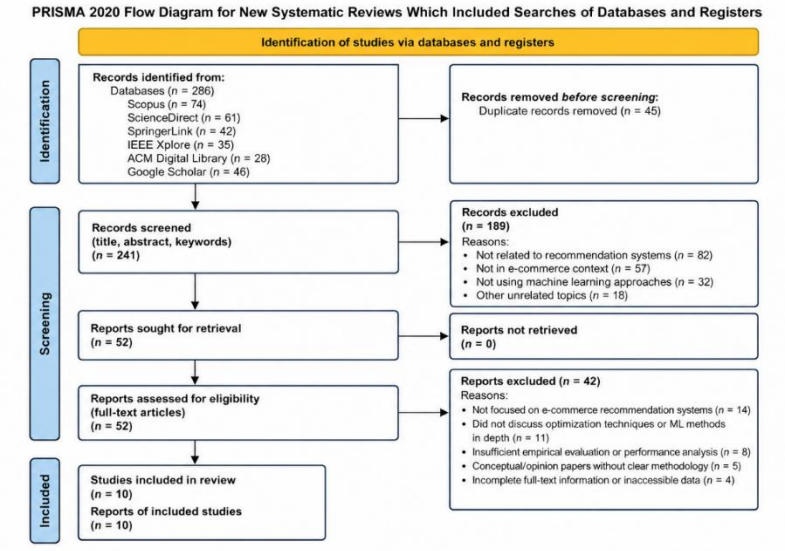

Figure 1. PRISMA 2020 Flow Diagram

Data extraction was conducted using a structured extraction form designed to collect key information from each study, including publication year, authors, research objectives, machine learning algorithms employed, optimization methods, evaluation metrics, key findings, and research contributions. The extracted data were then analyzed using thematic analysis, which enabled the identification of recurring themes, patterns, and relationships across the selected studies (Braun & Clarke, 2022).

The final synthesis organized the findings into several thematic categories, including machine learning algorithms for recommendation systems, optimization techniques for improving recommendation accuracy, evaluation approaches, implementation challenges, and emerging technological trends. Through this systematic process, the study provides a comprehensive overview of current research developments and offers evidence-based insights into future directions for optimizing recommendation systems on e-commerce platforms.

RESULTS

Following the PRISMA 2020 selection process, a total of 10 articles were identified as meeting all inclusion criteria and were subsequently included in the final review. These studies were published between 2020 and 2025 and focused on the development, implementation, evaluation, and optimization of machine learning–based recommendation systems within e-commerce environments. The selected articles represent a diverse range of machine learning approaches, including collaborative filtering, deep learning, graph neural networks, hybrid recommendation models, reinforcement learning, and large language model–based recommender systems. Collectively, these studies provide comprehensive insights into current optimization strategies, performance enhancement techniques, and emerging trends in e-commerce recommendation systems.

Table 1. Characteristics of the Selected Studies

No.	Author(s)	Year	Research Focus	Machine Learning Approach	Key Findings
1	Roy & Dutta	2022	Systematic review of recommender systems	Multiple ML approaches	Identified major challenges including sparsity, scalability, and personalization.
2	Portugal et al.	2020	Machine learning applications in recommender systems	Collaborative Filtering, Deep Learning	ML techniques significantly improve recommendation accuracy compared to traditional approaches.
3	Ezeife & Karlapalepu	2023	Sequential recommendation in e-commerce	Sequential Pattern Mining	User behavioral sequences enhance recommendation relevance and predictive performance.
4	Raza et al.	2025	Comprehensive review of modern recommender systems	Deep Learning, Neural Networks	Deep learning models outperform conventional recommendation techniques in complex datasets.
5	Poniszewska-Maranda et al.	2025	ML methods in e-commerce recommendations	Hybrid Machine	Hybrid approaches effectively

				Learning Models	address cold-start and data sparsity issues.
6	Makhmudov	2025	Optimization of e-commerce recommendation systems	Machine Learning and Deep Learning	Optimization techniques improve recommendation precision and customer satisfaction.
7	Tahir et al.	2025	Data-driven recommendation optimization	Deep Learning Models	Advanced neural architectures increase recommendation effectiveness and personalization.
8	Rajpoot et al.	2026	Emerging recommender system technologies	LLMs, Conversational AI	Large language models enhance contextual understanding and user interaction.
9	Salunke & Nichite	2022	Recommender systems in e-commerce	Collaborative Filtering	Data sparsity and scalability remain key implementation challenges.
10	Syamsuri et al.	2025	Consumer behavior prediction and recommendation	Machine Learning Algorithms	Behavioral prediction models improve recommendation relevance and purchase conversion rates.

The analysis of the selected studies shows that machine learning has become the primary foundation of modern e-commerce recommendation systems. While collaborative filtering remains widely used, recent developments increasingly employ deep learning, hybrid models, graph-based learning, and conversational recommender systems to improve recommendation accuracy and personalization.

A key finding is the effectiveness of hybrid approaches, which combine multiple techniques to address challenges such as cold-start problems, data sparsity, and limited recommendation diversity. In addition, user behavior analytics and sequential recommendation methods enable systems to better capture dynamic consumer preferences and deliver more relevant real-time recommendations.

The literature also highlights the emergence of large language models (LLMs), conversational AI, and multimodal recommendation systems, which enhance personalization through natural language interaction and contextual understanding. Despite these advancements, issues related to scalability, privacy, explainability, fairness, and computational efficiency remain important challenges for future research.

Based on the analysis of the 10 selected articles, four major themes emerged that illustrate the development, optimization strategies, and implementation challenges of machine learning–based recommendation systems in e-commerce platforms. These themes include: (1) Evolution of Machine Learning Algorithms in Recommendation Systems, (2) Optimization Strategies for Improving Accuracy and Personalization, (3) User Behavior Analytics as a Foundation for Adaptive Recommendations, and (4) Emerging AI Technologies and the Future of Recommendation Systems.

Evolution of Machine Learning Algorithms in Recommendation Systems

The first theme highlights a significant shift from traditional recommendation approaches toward more advanced and intelligent machine learning techniques. Early recommendation systems primarily relied on Collaborative Filtering (CF) and Content-Based Filtering (CBF) to predict user preferences. However, recent studies have demonstrated that these methods face limitations in handling large-scale datasets, cold-start problems, and data sparsity issues.

Most of the reviewed studies indicate that modern machine learning approaches, particularly Deep Learning, Neural Networks, and Hybrid Recommendation Models, significantly enhance the capability of recommendation systems to capture complex relationships between users and products. These approaches enable recommendation engines to generate more accurate predictions by extracting deeper behavioral patterns from user interactions compared to conventional methods.

Furthermore, recent research reveals an increasing adoption of representation-learning techniques such as embeddings and advanced neural architectures, allowing recommendation systems to learn user preferences dynamically. These findings suggest that the evolution of machine learning algorithms has become a fundamental driver in improving recommendation quality within modern e-commerce ecosystems.

Optimization Strategies for Improving Recommendation Accuracy and Personalization

The second theme focuses on the various optimization strategies employed to enhance recommendation system performance. Nearly all reviewed studies emphasize that recommendation accuracy is a critical indicator of system effectiveness because it directly influences user satisfaction, engagement, and purchasing decisions.

One of the most commonly identified strategies is the implementation of Hybrid Recommendation Systems, which combine multiple recommendation

techniques to overcome the weaknesses of individual approaches. Hybrid models have proven effective in addressing cold-start problems, increasing recommendation diversity, and improving predictive performance in complex e-commerce environments.

In addition, several studies implemented deep learning–based optimization techniques to enhance precision, recall, and ranking performance. Advanced neural network architectures enable recommendation systems to process massive amounts of data and generate highly personalized recommendations tailored to individual user characteristics. These findings indicate that optimization efforts extend beyond improving prediction accuracy and also focus on creating more relevant and engaging shopping experiences.

User Behavior Analytics as a Foundation for Adaptive Recommendation Systems

The third theme demonstrates that user behavior analytics has become a crucial component in the development of modern recommendation systems. Numerous studies highlight the importance of utilizing behavioral data, including browsing history, product clicks, purchase transactions, customer reviews, and navigation patterns, to generate more effective recommendations. Approaches based on Sequential Recommendation and Behavior Prediction Models enable systems to understand how user preferences evolve over time. By continuously analyzing user interactions, recommendation systems can provide adaptive and context-aware suggestions that better match users' current interests and needs.

The reviewed literature indicates that recommendation systems incorporating user behavior analytics achieve higher relevance and effectiveness than systems relying solely on static product information or historical purchase records. Consequently, user behavior analysis has emerged as one of the key factors driving recommendation system optimization in e-commerce platforms.

Emerging AI Technologies and the Future of Recommendation Systems

The final theme reveals the emergence of new artificial intelligence technologies that have the potential to transform recommendation systems in the coming years. Several recent studies emphasize the integration of Large Language Models (LLMs), Conversational AI, and Multimodal Recommendation Systems as key directions for next-generation recommendation technologies.

LLMs enable recommendation systems to understand user preferences, intentions, and contextual information through sophisticated natural language interactions. Meanwhile, conversational recommender systems allow users to communicate directly with recommendation engines in a manner similar to interacting with virtual assistants. These capabilities significantly improve the interactivity, responsiveness, and personalization of recommendations.

Additionally, multimodal recommendation systems integrate multiple forms of data—including text, images, audio, and behavioral signals—to develop a more comprehensive understanding of consumer preferences. Despite these promising advancements, the literature also highlights ongoing challenges related to scalability, data privacy, explainability, fairness, and computational

resource requirements. Addressing these challenges will be essential for the successful adoption of emerging AI-powered recommendation technologies.

Overall, the thematic findings indicate that the optimization of machine learning–based recommendation systems in e-commerce has evolved beyond merely improving predictive accuracy. Contemporary developments increasingly emphasize the creation of personalized, adaptive, and interactive user experiences through the integration of advanced artificial intelligence technologies capable of understanding user behavior, context, and preferences in real time.

DISCUSSION

The findings of this systematic literature review demonstrate that the optimization of machine learning–based recommendation systems has become a central concern in the development of modern e-commerce platforms. As digital marketplaces continue to expand, recommendation systems are increasingly expected not only to predict user preferences accurately but also to provide personalized, adaptive, and context-aware shopping experiences. The thematic analysis revealed four major dimensions of optimization, namely the evolution of machine learning algorithms, optimization strategies for accuracy and personalization, the utilization of user behavior analytics, and the emergence of advanced artificial intelligence technologies. Together, these themes illustrate how recommendation systems have evolved from simple filtering mechanisms into intelligent decision-support tools that significantly influence consumer purchasing behavior and business performance.

The first thematic finding highlights the ongoing evolution of machine learning algorithms in recommendation systems. Traditional recommendation techniques, such as collaborative filtering and content-based filtering, have long served as the foundation of recommender systems due to their simplicity and effectiveness in structured environments. However, the reviewed studies indicate that these approaches often struggle with challenges such as data sparsity, cold-start problems, and scalability limitations. This finding aligns with the observations of Roy and Dutta (2022), who argue that conventional recommendation models face increasing difficulties in handling the complexity and diversity of contemporary e-commerce datasets. Consequently, many researchers have shifted toward advanced machine learning techniques, particularly deep learning architectures and hybrid recommendation models. These approaches enable systems to capture complex nonlinear relationships among users, products, and contextual factors, thereby improving predictive performance and recommendation relevance. The transition toward more sophisticated learning models reflects the broader trend of integrating artificial intelligence into digital commerce to enhance user experiences and competitive advantage.

The second theme emphasizes the importance of optimization strategies for improving recommendation accuracy and personalization. The reviewed studies consistently show that recommendation quality is strongly associated with user satisfaction, engagement, and conversion rates. Hybrid recommendation systems

emerged as one of the most effective optimization strategies because they combine the strengths of multiple recommendation approaches while mitigating their individual weaknesses. This finding supports previous research suggesting that hybrid models provide greater robustness and flexibility when dealing with heterogeneous user data and dynamic product catalogs. Furthermore, deep learning–based optimization techniques were found to improve recommendation precision by extracting latent behavioral patterns from large-scale datasets. These findings suggest that optimization should not be viewed solely as a technical enhancement process but rather as a strategic mechanism for improving customer experience and business outcomes. In highly competitive e-commerce environments, the ability to deliver relevant and personalized recommendations has become a critical determinant of customer retention and long-term profitability.

Another significant finding concerns the growing role of user behavior analytics in recommendation system optimization. The reviewed studies reveal that recommendation systems increasingly rely on behavioral data such as browsing histories, clickstreams, purchase transactions, and customer feedback to understand user preferences more accurately. This shift reflects the recognition that consumer preferences are dynamic rather than static and therefore require continuous monitoring and adaptation. Sequential recommendation models and behavior prediction techniques allow systems to identify temporal patterns and anticipate future user needs. As a result, recommendation systems can provide more context-sensitive and timely suggestions that align with evolving consumer interests. This finding is consistent with the broader literature on data-driven personalization, which emphasizes the importance of leveraging behavioral intelligence to improve recommendation relevance and user engagement. The integration of user behavior analytics also demonstrates the growing convergence between recommendation systems, predictive analytics, and customer relationship management within digital commerce ecosystems.

The fourth theme highlights the transformative potential of emerging artificial intelligence technologies, particularly large language models (LLMs), conversational AI, and multimodal recommendation systems. The reviewed literature suggests that these technologies represent the next stage in the evolution of recommendation systems. Unlike traditional recommendation approaches that primarily rely on structured interaction data, LLMs can interpret natural language inputs, understand contextual information, and generate recommendations through conversational interactions. Similarly, conversational recommender systems allow users to refine their preferences dynamically through dialogue, creating a more interactive and human-centered recommendation experience. Multimodal recommendation systems further extend these capabilities by integrating multiple forms of information, including text, images, audio, and behavioral signals. These innovations have the potential to significantly improve recommendation relevance, explainability, and user satisfaction. However, their implementation also introduces new challenges related to computational complexity, data management, and model transparency.

Despite the significant advancements identified in the reviewed studies, several persistent challenges remain. Data sparsity continues to limit the effectiveness of recommendation systems, particularly for new users and newly introduced products. Likewise, the cold-start problem remains a critical issue in many e-commerce environments where user interaction histories are insufficient for generating reliable recommendations. Scalability is another major concern, as recommendation systems must process increasingly large volumes of user and product data while maintaining real-time responsiveness. Furthermore, the growing use of machine learning and artificial intelligence raises important concerns regarding privacy, fairness, explainability, and ethical data usage. Consumers and regulatory bodies increasingly demand transparency regarding how recommendation algorithms operate and how personal data are collected and utilized. Therefore, future optimization efforts must balance predictive performance with ethical and regulatory considerations to ensure sustainable and trustworthy recommendation practices.

The findings also reveal several opportunities for future research. First, further investigation is needed into explainable recommendation systems that can provide transparent justifications for recommendation outcomes. Such systems may improve user trust and acceptance while addressing concerns related to algorithmic opacity. Second, future studies should explore the integration of reinforcement learning and real-time adaptive learning mechanisms to enhance recommendation responsiveness in rapidly changing environments. Third, the growing adoption of large language models presents opportunities to develop more sophisticated conversational recommendation systems capable of understanding complex user intentions and preferences. Finally, future research should examine the effectiveness of multimodal recommendation frameworks in capturing richer consumer information and delivering more comprehensive personalization strategies.

Overall, this review demonstrates that the optimization of machine learning–based recommendation systems has become a multidimensional process involving algorithmic innovation, behavioral analytics, personalization strategies, and emerging artificial intelligence technologies. The evolution of recommendation systems reflects a broader transformation in e-commerce, where intelligent systems increasingly shape consumer experiences and business competitiveness. Consequently, organizations seeking to enhance customer engagement and commercial performance should prioritize the continuous optimization of recommendation systems while simultaneously addressing challenges related to scalability, transparency, privacy, and ethical implementation. Such efforts will be essential for developing the next generation of intelligent and user-centered e-commerce platforms.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that the optimization of machine learning–based recommendation systems has become a critical component of modern e-commerce platforms. The systematic review revealed that recommendation technologies have evolved from traditional collaborative filtering approaches toward more

sophisticated solutions, including deep learning models, hybrid recommendation systems, sequential recommendation techniques, and large language model–based architectures. These advancements have significantly improved recommendation accuracy, personalization, and user engagement.

The findings further indicate that hybrid optimization strategies and user behavior analytics play essential roles in addressing challenges such as data sparsity, cold-start problems, and dynamic consumer preferences. Moreover, emerging technologies such as conversational AI, multimodal recommendation systems, and large language models offer substantial opportunities for developing more intelligent, adaptive, and context-aware recommendation experiences.

Despite these technological improvements, several challenges remain unresolved, including scalability, explainability, fairness, privacy protection, and computational efficiency. Therefore, future research should focus on developing transparent and trustworthy recommendation systems that balance predictive performance with ethical and regulatory considerations. Overall, continuous optimization of machine learning–based recommendation systems is essential for enhancing customer satisfaction, strengthening competitive advantage, and supporting sustainable growth in the e-commerce sector**.**

FURTHER STUDY

Future research could further optimize machine learning–based recommendation systems on e-commerce platforms by integrating more advanced algorithms, such as deep learning, reinforcement learning, and hybrid recommendation approaches. Researchers may also consider incorporating contextual factors, real-time user behavior, product reviews, purchasing history, and demographic characteristics to improve recommendation accuracy and personalization. In addition, future studies could evaluate the performance of recommendation systems using larger and more diverse datasets across different e-commerce platforms, while examining their impact on customer satisfaction, purchase intention, customer loyalty, and overall business performance. Attention should also be given to issues of data privacy, algorithmic bias, transparency, and fairness to ensure that recommendation systems are not only effective but also responsible and trustworthy.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to all parties who contributed to the completion of this research entitled Optimization of Machine Learning–Based Recommendation Systems on E-Commerce Platforms. Special appreciation is extended to the academic supervisors, research colleagues, and institutions for their valuable guidance, support, constructive feedback, and access to the resources required throughout the research process. The authors also thank all individuals and parties who provided data, information, and assistance in supporting the development and evaluation of the proposed recommendation system. Their contributions were essential to the successful completion of this study.

REFERENCES

Braun, V., & Clarke, V. (2022). Thematic Analysis: A Practical Guide. SAGE Publications.

Castells, P., & Jannach, D. (2023). Recommender systems: A primer. arXiv. https://arxiv.org/abs/2302.02579

Ezeife, C. I., & Karlapalepu, H. (2023). A survey of sequential pattern based e-commerce recommendation systems. Algorithms, 16(10), 467. https://doi.org/10.3390/a16100467

Felfernig, A., Tran, T. N. T., Le, V. M., Popescu, A., Uta, M., & Atas, M. (2024). Knowledge-based recommender systems: Overview and research directions. User Modeling and User-Adapted Interaction, 34(1), 1–49.

Karimova, F. (2016). A survey of e-commerce recommender systems. European Scientific Journal, 12(34), 75–89. https://doi.org/10.19044/esj.2016.v12n34p75

Kitchenham, B., & Charters, S. (2007). Guidelines for Performing Systematic Literature Reviews in Software Engineering. EBSE Technical Report, Keele University and Durham University.

Makhmudov, S. (2025). Machine learning-based recommendation systems for e-commerce platforms: A comprehensive review. MATRIX Academic International Online Journal of Engineering and Technology, 8(2), 1–12.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

Poniszewska-Maranda, A., Pakula, M., & Borowska, B. (2025). Recommendation systems in e-commerce applications with machine learning methods. arXiv. https://arxiv.org/abs/2506.17287

Portugal, I., Alencar, P., & Cowan, D. (2018). The use of machine learning algorithms in recommender systems: A systematic review. Expert Systems with Applications, 97, 205–227. https://doi.org/10.1016/j.eswa.2017.12.020

Rajpoot, C. S., Tiwari, V., & Vishwakarma, S. K. (2026). Emerging trends of recommender system for e-commerce: A comprehensive review. Discover Computing, 29(63), 1–34.

Raza, S., Rahman, M., Kamawal, S., Toroghi, A., Raval, A., Navah, F., & Kazemeini, A. (2025). A comprehensive review of recommender systems: Transitioning from theory to practice. Computer Science Review, 56, 100849.

Roy, D., & Dutta, M. (2022). A systematic review and research perspective on recommender systems. Journal of Big Data, 9(59), 1–38. https://doi.org/10.1186/s40537-022-00592-5

Salunke, T., & Nichite, U. (2022). Recommender systems in e-commerce. arXiv. https://arxiv.org/abs/2212.13910

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Syamsuri, A. R., Arohman, R., Saputra, M. R., Ikhlash, M., & Damanik, S. K. (2025). Integration of machine learning in e-commerce: A systematic literature review on consumer behavior prediction and product recommendation. Social Sciences Insights Journal, 4(1), 45–61.

Tahir, M. R., Nazir, N., Ishaq, K., & Ahmed, S. (2025). A data-driven review of machine learning techniques for e-commerce product recommendation systems. International Journal of Innovations in Science & Technology, 7(3), 1–15.

Xiao, Y., & Watson, M. (2019). Guidance on conducting a systematic literature review. Journal of Planning Education and Research, 39(1), 93–112. https://doi.org/10.1177/0739456X17723971