

# "A Study of E-Commerce Product Consumption Analysis and Visualization"

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## ABSTRACT

In the current paper researcher says that this review presents a comprehensive overview of many methodologies used in recent years to visualize, predict customer behavior and segment using data analysis and machine learning. It introduce new trends such as pictorial storytelling with data, AI driven personalization, real-time behavioral analysis and deep learning prediction models as fundamental influencers for the next generation of e-commerce platforms. The paper also suggest future research directions like hybrid model development (combine two or more methods), protecting user privacy, and adaptive visualization systems that can help businesses make better decisions and customer engagement in online retail ecosystems.

**Keywords:** E-Commerce Product Consumption Analysis, Machine Learning–Driven Visualization, Consumer Behavior Analytics, Interactive Visual Analytics, Real-Time Predictive Analysis, AI-Powered Decision Support

## INTRODUCTION

In the age of digital innovation, e-commerce has transformed the way Consumers respond with products and services, Emergence of a data-driven world where each click, purchase leaves and view producing actionable usage patterns. The rapid growth of digital shopping, Stimulated by enhanced user-centric digital design, the combination of customized user experiences and widespread mobile usage has led to a significantly growth in user behavioral data within the e-commerce space. Digital transformation presents immense potential through large-scale data reflecting user and market insights; yet it demands sophisticated analytical models convert this raw data into practical insights.

Confront this challenge; machine learning (ML) and data visualization have materialized as innovative technologies. Data visualization triggers the transformation of maps complex information into user-friendly visual aids, allowing influencers to track trends, patterns and unexpected behaviors in consumer interactions ([1], [2]).By mapping conceptual data into graphical illustrations like as graphs, dashboards and heat maps visualization promotes more approachable ,faster and more effective decision-making. In e-commerce environments, it Facilitators in observing user behavior patterns, monitoring sales process flows, observing product performance, and tracking user participation.

Simultaneously, machine learning algorithms have indicated powerful capabilities in detecting underlying trends, Predicting with precision, and enabling personalization at scale. Mechanisms such as recommendation systems, clustering, classification and deep learning have become crucial in applications such as demand forecasting, churn prediction, customer segmentation and dynamic price([4], [5], [6],[8]). For instance, the synthesis of RFM (Recency, Frequency, Monitory) models with clustering methods like K-Means boosts focused marketing strategies by grouping customers for specific actions([9]). More advanced methods using NLP (natural language processing) and deep neural network allow for uncovering customer needs through unstructured data such as queries, reviews and live-chat messages ([11]).

Recent studies are the blending of Explainable AI (XAI) with customer behavior analytics to ensure that insights from machines are easy to understand and respect security of user ([8]). This is especially important

when it comes to customization recommendations and tracing user behavior in real time, where it's compulsory to keep transparency of algorithms and develop customer trust. Moreover, investigators are also using click-stream data, AI-based customized tools, and behavioral models to better understand how customers choose products online ([2], [3], [7]).

The most important thing is that especially when online stores give you customized recommendations or analysis of what you are doing in live. There's also need to merge different types of data (such as purchases, behavior and text) into unified models that gives a holistic insights into customer behaviour.

The review paper aims to synthesize and evaluate current research trends related to clickstream data (where you click on a website), AI-powered recommendation systems, and even how your brain-stream makes decisions live, helps to build smarter, faster and more ethical e-commerce systems.

Real-time interactive visualizations now integrate AI for predictive trends and anomaly detection. The data storytelling uses visuals and summaries for better interpretation. Some visualization tools are Tableau, Power BI, and D3.js, and these visualization tools provide live integration of e-commerce data.

Graph-based clustering and SOM are used as new techniques for customer segmentation if the behavior data is complex. The e-commerce firms adopt dynamic segmentation, and dynamic segmentation uses continuously updated segments using the software like Apache Kafka.

The growing trend of using AutoML tools such as Google AutoML and H2O.ai can help the marketers in building the ML models without writing codes. The use of reinforcement learning for recommendation and transfer learning for using the same model for similar products saves a lot of efforts and time.

There are modern applications of neuro-marketing by e-commerce platforms. For instance, scarcity signals, social proof, and anchoring are used to influence customers' decisions. Such tools as eye-tracking and UX heatmaps are employed for users' behavior analysis while urgency messages are used as subconscious cues ("Only 2 left!"). Xiong et al. [13] have applied BERT-BiLSTM approach for the analysis of live chat messages in e-commerce, thus, enabling real-time understanding of customers' sentiment and intentions. It facilitates context-aware recommendations. Suryadi and Putra [12] have analyzed deep learning models (CNN, LSTM, GRU) to forecast consumers' behaviour.

## REVIEW METHODOLOGY

These papers are taken from Google Scholar, IEEE Xplore, ScienceDirect, and Springer, published from 2021 till 2024. "E-commerce", "customer behavior", "machine learning", "data visualization" and "customer segmentation" were the keywords that were used to find relevant literature. In total, 50 papers were found during initial database search. The screening process of literature revealed 30 articles to be analyzed in detail. According to the inclusion criteria defined in this review, namely English language, peer-reviewed journal/conference papers related to the analysis of product consumption in e-commerce, visualization of results and machine learning, 14 papers of high relevance were chosen. The selection emphasized quality over quantity to ensure focused and meaningful analysis, while additional studies may be considered in future extended review work.

## LITERATURE REVIEW

### 1. Data Visualization in E-Commerce Platforms

Visualization requires for turning complex datasets into meaningful insights. Yu and Xu [1] proposed interactive visual selection system for e-commerce sites allowing users to filter and compare products. Likewise, Sharma and Das [2] implemented dynamic dashboard tools that analyze clickstream behavior aiming to make the interface easy for marketers to use. These studies collectively show that intelligent visualization can lighten users' mental workload while streamlining the product identification more efficient.

## 2. Clustering Techniques and Customer Segmentation

Artificial Intelligence (AI) is changing how e-commerce platforms personalize shopping experiences by adapting content and recommendations customer's preferences. choosing the most appropriate machine learning algorithms becomes important for analyzing meaningful insights from large datasets, thereby influencing the accuracy and efficiency of predictions. Yang [4,10] examined various machine learning models, such as Decision Trees, SVM, and Neural Networks, for understand patterns in e-commerce data. Similarly, Rahib et al. [13] used ML techniques to predict customer behavior from transactional data, and Patel [14] applied conventional data mining approaches (e.g., classification and association rule mining) to Improve customer service strategies.

Customer segmentation is a key component of analysis of consumer behavior. Wasilewski et al. [6] presented a detailed comparison of clustering algorithms, including K-Means, DBSCAN and hierarchical clustering, designed for e-commerce datasets. As part of such an approach, Hu et al. [5] applied clustering techniques in their marketing process while Siagian et al. [9] used clustering based on the LRFM model combined with K-means to build accurate customer profiles. Another example is the work done by Talaat et al. [8] who have introduced deep learning and Explainable AI in their segmentation.

## 3. Machine Learning Applications in Consumption Analysis

Customer groups are essential for marketing efforts in order to be effective. Methods of clustering, such as DBSCAN, K-Means, and hierarchical clustering can help companies learn customers' purchasing behavior and make recommendations accordingly. Hu et al. [5] have used K-Means clustering in big data environments for precision marketing purposes. Wasilewski et al. [6] have conducted comparison analysis of different approaches to clustering and have selected best practices of clustering. Talaat et al. [8] suggested a mixed approach for segmentation based on deep learning, Explainable Artificial Intelligence (XAI), and RFM criteria. Siagian et al. [9] improved this approach by adding Logistic regression and LRFM-K-Means clustering to develop better marketing strategies. Furthermore, Nguyen et al. [7] incorporated psychology into their approach through use of the serial mediation model to examine the effects of vulnerability perception on online purchases.

Machine Learning has significance in the analysis of consumption. Yang [4, 10] has considered various methods of Machine Learning such as Decision Trees, SVM, and Neural Networks, which can help in finding out meaningful relationships in complicated data of e-commerce. In addition to this, Rahib et al. [13] have considered how historical transaction data can be made use of in predicting consumer behavior using machine learning techniques. In addition, Patel [14] has used classical methods of data mining like association rule mining and classification in order to improve services provided by e-commerce websites. Yang [4], [11] have suggested the specific learning system for use with e-commerce data, and proved that supervised and unsupervised learning approaches can successfully reveal behavioral patterns.

## 4. Behavioral and Psychological Modeling

The Consistency of Analytical models can help improve by incorporating the psychological insight of online consumer behavior. Nguyen et al. [7] developed a serial mediation framework that linking consumer vulnerability with purchasing behavior, adding a behavioral insight into data-centric methodologies. Additionally Raji et al. [3] The study showed that twofold role of AI-based personalization in lead user Interaction and raising ethical issues like over-targeting and potential misuse of personal information.

## 5. Natural Language Processing and Real-time Analysis

The application of Natural Language Processing (NLP) in real-time e-commerce analytics is on the rise. Xiong et al. [11] The scientists used the BERT-BiLSTM model to detect the customer sentiment and intentions from live chat for real-time emotional-aware product recommendations. Similarly, Suryadi and Putra [12] explored deep learning models like CNN, LSTM, and GRU for predicting customer behavior in CRM systems. Text mining and sentiment analysis offer a fine-grained understanding of the consumer intention. Xiong et al. [13]

extract sentiment and intent from live e-commerce chat data, proceeding towards real-time and context-aware recommendation systems. Such methods enable the businesses to personalize the interactions in real-time, based on the changing user emotions and languages.

| S.No | Paper Title                                                                             | Parameters                                                                                          |
|------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| 1    | Application Research of Data Visualization in the E-Commerce Product Selection Platform | Product attributes, user interaction, sales metrics, visualization dashboards, decision efficiency  |
| 2    | Dynamic Data Visualization and Clickstream Data Analytic for E-Commerce                 | Clickstream data, page views, session duration, bounce rate, conversion rate                        |
| 3    | E-commerce and Consumer Behavior: AI-powered Personalization                            | Customer preferences, purchase history, browsing behavior, personalization, recommendation accuracy |
| 4    | Intelligent Analysis Method of E-commerce Data (OJBM)                                   | Input features, ML algorithms, accuracy, training/testing data                                      |
| 5    | Precision Marketing using Cluster Analysis                                              | Demographics, purchase frequency, spending behavior, clusters, marketing response                   |
| 6    | Multi-factor Evaluation of Clustering Methods                                           | Number of clusters, silhouette score, distance metrics, efficiency                                  |
| 7    | Consumers' Vulnerability and Purchase Behavior                                          | Trust, risk, vulnerability, purchase intention, psychological factors                               |
| 8    | Customer Segmentation using Deep Learning + RFM                                         | Recency, frequency, monetary, deep learning features, explainability                                |
| 9    | Customer Segmentation using K-means and LRFM                                            | Length, recency, frequency, monetary, clustering                                                    |
| 10   | Intelligent Analysis Method                                                             | Dataset size, feature selection, accuracy, error rate                                               |
| 11   | Consumption Intent using BERT-BiLSTM                                                    | Text features, sentiment, embeddings, intent prediction                                             |
| 12   | Predicting Consumption Intention using Deep Learning                                    | Customer interaction, engagement, neural network features, prediction                               |
| 13   | Customer Data Prediction using ML                                                       | Demographics, transactions, feature importance, accuracy, precision, recall                         |
| 14   | Data Analysis for E-Commerce using Data Mining                                          | Customer data, purchase patterns, association rules, classification                                 |

### Comparative study table

| Ref. | Paper        | Method                                    | Strength                                                   | Drawback                                       | Used For                        |
|------|--------------|-------------------------------------------|------------------------------------------------------------|------------------------------------------------|---------------------------------|
| [1]  | Yu & Xu      | Data Visualization, Interactive Dashboard | Enhances product comparison efficiency and decision-making | Does not integrate machine learning techniques | Product selection visualization |
| [2]  | Sharma & Das | Clickstream Analysis, Dynamic             | Provides insights into user clickstream                    | Limited predictive capability                  | Clickstream behavior analysis   |

|      |                   | Visualization                                    | behavior                                                  |                                                    |                                  |
|------|-------------------|--------------------------------------------------|-----------------------------------------------------------|----------------------------------------------------|----------------------------------|
| [3]  | Raji et al.       | AI-Based Personalization Review                  | Provides strong understanding of consumer behavior trends | Mostly theoretical; lacks practical implementation | Consumer behavior analysis       |
| [4]  | Yang              | Decision Tree, SVM, Neural Networks              | High predictive capability for pattern discovery          | No visualization layer included                    | E-commerce data analysis         |
| [5]  | Hu et al.         | K-Means Clustering                               | Effective for grouping customers with similar behavior    | Sensitive to initial cluster selection             | Precision marketing              |
| [6]  | Wasilewski et al. | K-Means, DBSCAN, Hierarchical Clustering, TOPSIS | Comprehensive comparative clustering analysis             | Low interpretability for business users            | Clustering comparison            |
| [7]  | Nguyen et al.     | Serial Mediation Model                           | Incorporates psychological factors in purchasing behavior | Limited use of machine learning techniques         | Purchase behavior analysis       |
| [8]  | Talaat et al.     | Deep Learning + Explainable AI + RFM             | High prediction accuracy with explainability              | High computational complexity                      | Customer segmentation            |
| [9]  | Siagian et al.    | LRFM + K-Means                                   | Improves customer profiling accuracy                      | Limited scalability with large datasets            | Customer segmentation            |
| [10] | Yang              | ML Algorithms (Decision Tree, SVM, ANN)          | Identifies hidden behavioral patterns                     | Lacks real-time analytics capability               | Intelligent e-commerce analytics |
| [11] | Xiong et al.      | BERT-BiLSTM                                      | Accurately detects sentiment and consumption intent       | Computationally expensive                          | Consumption intent prediction    |
| [12] | Suryadi & Putra   | CNN, LSTM, GRU (Review)                          | Strong temporal behavior prediction capability            | Review only; no practical implementation           | Consumer behavior prediction     |
| [13] | Rahib et al.      | Machine Learning Prediction Models               | Useful for predicting customer behavior                   | Uses historical data only                          | Customer data prediction         |
| [14] | Patel             | Classification, Association Rule Mining          | Effective for discovering hidden patterns                 | Relies on traditional methods                      | Customer service improvement     |

## Case Study

Amazon provides a strong real-world example of my research topic. It makes use of machine learning techniques to understand the product consumption patterns such as buying frequency, product demands, and customer preferences. The results obtained from machine learning techniques are depicted using visual analytics.

## CONCLUSION

This review evaluates the recent advancements in applying machine learning and data visualization to make sense of what products customers buy in online stores. It emphasizes that group customers, such as DBSCAN, RFM (recency, frequency, and monetary) value analysis and K-Means using advanced deep learning techniques are very effective for segmenting customers and aiming marketing strategies. Tools like visual dashboards and clickstream analysis help companies to make smarter choices. Also new AI language tools like BERT-BiLSTM models are instantly figure out what customers intend to do.



However, we still hurdles persist like understanding why a model makes certain suggestions, making sure this system can fast enough in real-time for everyone crucially, respecting people's privacy. Future research should focus to make AI models more transparent (easier to understand), building systems that can learn and adapt, and carefully balancing personalized experiences and keeping your personal information safe.

The literature review conducted for this topic included recent literature on e-commerce product consumption analysis, machine learning, and visualization techniques. From the literature, it is seen that the application of machine learning techniques such as clustering, classification, and deep learning in understanding consumer behavior and making predictions with the help of visualization has improved the analytical skills and decision-making process. However, there are various limitations that exist, which include the absence of combined machine learning based visualization systems, minimal attention being paid to consumption analysis at the product level, static visualization systems, lack of scalability, poor interpretability of the machine learning output, and lack of real-time analytics. Moreover, role-based customization and assessment of effectiveness of the visualization method is something that has not yet been explored adequately. The future of research should be on developing scalable, real-time, and interactive visualization technologies with advanced machine learning and Explainable Artificial Intelligence (XAI) to give deep and understandable insights for informed decision making in e-commerce settings.

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