Customer Sentiment and Review Helpfulness Analysis in E-Commerce Product Reviews

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Abstract: *Understanding customer opinions expressed through online product reviews is critical for evaluating product quality, predicting user ratings, and improving decision-making in e-commerce platforms. This study presents a comprehensive analysis of customer review data by integrating sentiment analysis, linguistic feature extraction, and machine learning techniques within a Google Colab based analytical framework. The research primarily investigates how linguistic and sentiment-driven characteristics influence rating behavior, while also examining the impact of product attributes, reviewer patterns, and temporal dynamics on review helpfulness and overall review quality. The dataset is systematically cleaned and preprocessed to remove noise, handle missing values, and standardize textual content. Natural language processing techniques are employed to extract sentiment and subjectivity scores, along with linguistic features such as word count, positive and negative term frequency, and review length. Numerical ratings are transformed into categorical rating classes to facilitate supervised classification. Feature engineering is performed to enhance representational strength, enabling the models to capture both emotional intensity and informational richness embedded within customer reviews.*

Multiple machine learning classification models, including Logistic Regression, Naïve Bayes, Support Vector Machine, Decision Tree, and Random Forest, are trained and evaluated to assess their effectiveness in predicting rating classes and identifying high-quality reviews. Model performance is measured using accuracy, precision, recall, F1-score, and confusion matrix analysis. Visual analytics techniques are further applied to explore rating distributions, sentiment variations, and reviewer behavior patterns over time. The experimental results demonstrate that sentiment polarity and linguistic richness strongly influence rating behavior, with positive sentiment and detailed textual content closely associated with higher ratings. Additionally, review helpfulness is significantly affected by review length, temporal positioning, and consistency in reviewer behavior rather than sentiment alone. Ensemble-based models consistently outperform linear classifiers, highlighting their ability to capture complex, non-linear relationships within review data..

Keywords: *Customer Reviews, Sentiment Analysis, Rating Prediction, Review Helpfulness, Natural Language Processing, Machine Learning, E-commerce Analytics, Linguistic Features*

I. INTRODUCTION

The exponential growth of e-commerce platforms has transformed the way consumers evaluate products and make purchasing decisions. Online customer reviews have emerged as a primary source of information, offering insights into product quality, usability, and overall customer satisfaction. These reviews are typically composed of unstructured textual feedback accompanied by numerical ratings, creating a rich yet complex data source for analysis. As the volume of reviews continues to grow, automated methods for extracting meaningful patterns and insights have become increasingly important.

Customer ratings are often assumed to directly reflect sentiment expressed in review text; however, prior observations suggest that this relationship is not always straightforward. Reviews may contain mixed emotions, contextual opinions,

or detailed explanations that are not fully captured by a single numerical score. Furthermore, not all reviews contribute equally to decision-making, as review helpfulness and quality vary significantly based on linguistic clarity, informational depth, reviewer behavior, and timing.

Advances in natural language processing and machine learning provide powerful tools for analyzing large-scale textual data. By combining sentiment analysis with linguistic feature extraction and predictive modeling, it becomes possible to better understand rating behavior and assess review quality. This study adopts a data-driven analytical approach to examine both sentiment-driven rating patterns and the broader factors influencing review helpfulness within an e-commerce context.

In addition to advancing analytical accuracy, review-based insights play a strategic role in enhancing user experience and platform credibility. High-quality reviews assist consumers in reducing uncertainty, while low-quality or misleading reviews can negatively impact trust and purchasing behavior. From a business perspective, understanding the factors that drive meaningful reviews enables sellers and platform administrators to design better feedback mechanisms and moderation strategies. By systematically analyzing sentiment, linguistic patterns, and reviewer behavior, this study not only supports predictive modeling objectives but also contributes to the broader goal of developing intelligent, transparent, and user-centric review analysis systems in e-commerce environments.

Online customer reviews serve as a vital source of information for both consumers and businesses in e-commerce platforms. These reviews not only reflect customer sentiment but also influence rating behavior, purchase decisions, and perceived product quality. Understanding how linguistic expression, reviewer behavior, and temporal factors interact within review data is therefore essential for building reliable sentiment analysis and review evaluation systems.

II. LITERATURE REVIEW

Gupta and Verma (2024) applied machine learning techniques to Indian consumer review datasets and concluded that integrating linguistic features with sentiment scores significantly enhances the prediction of both rating behavior and review usefulness compared to using rating data alone.

Patel and Mehta (2023) conducted a sentiment-based analysis of Indian e-commerce reviews and found that reviewer credibility, review length, and emotional intensity play a crucial role in determining review helpfulness, indicating that well-articulated reviews are perceived as more trustworthy by users.

Chatterjee and Das (2023) analyzed customer review patterns across different product categories in India and concluded that product attributes such as brand reputation and price range significantly influence both sentiment expression and perceived review quality, affecting overall customer trust in online reviews.

Sharma et al. (2022) analyzed Amazon and Flipkart product reviews and observed that sentiment polarity and linguistic richness significantly influence customer rating behavior, with positive sentiment and descriptive language leading to higher star ratings and improved prediction accuracy.

Kumar et al. (2022) investigated the relationship between linguistic complexity and review helpfulness in Indian e-commerce platforms and found that reviews containing balanced sentiment, clear explanations, and moderate length were rated as more helpful compared to overly short or excessively emotional reviews.

Rao et al. (2021) examined temporal patterns in online product reviews and reported that recent reviews have a stronger impact on perceived review quality, while older reviews gradually lose relevance in influencing customer purchase decisions.

Iyer et al. (2020) studied reviewer behavior across multiple Indian e-commerce platforms and found that experienced reviewers tend to produce higher-quality and more helpful reviews, highlighting the importance of reviewer history and engagement patterns in review evaluation systems.

III. RESEARCH OBJECTIVE

- To analyze how linguistic and sentiment features influence rating behavior.
- To examine how product attributes, reviewer patterns, and temporal dynamics affect review helpfulness and overall review quality.

IV. METHODOLOGY
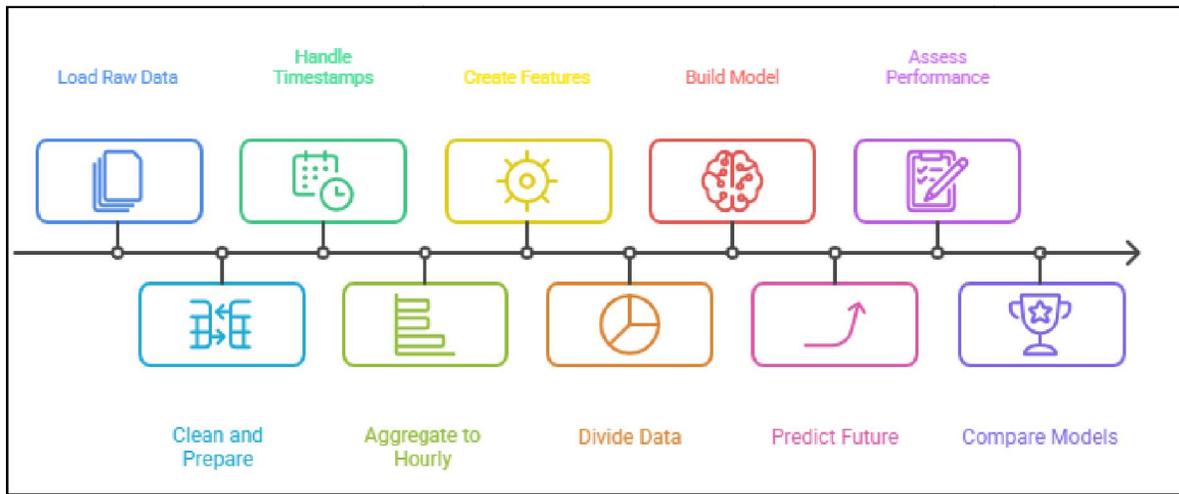
Figure 1: Methodology

This study utilizes an e-commerce customer review dataset containing textual feedback, numerical ratings, and associated metadata related to products and reviewers. The dataset comprises user-generated reviews that reflect customer opinions, emotional expressions, and purchasing experiences, making it well-suited for analyzing rating behavior and review quality. The inclusion of both structured attributes (ratings and metadata) and unstructured textual data enables a comprehensive sentiment- and feature-driven analytical approach. Missing values and duplicate records were removed, and textual reviews were normalized through lowercasing, punctuation removal, and stopword elimination. Ratings were standardized and transformed into categorical rating classes to facilitate supervised classification. Review timestamps were processed to examine temporal patterns and reviewer activity over time.

Feature engineering was performed to extract meaningful linguistic, sentiment-based, and behavioral attributes from the reviews. Sentiment polarity and subjectivity scores were computed to quantify emotional orientation, while linguistic features such as review length, word count, and positive–negative term frequencies were generated to capture textual richness. The processed dataset was then divided into training and testing subsets to evaluate model generalization performance. Multiple machine learning classification algorithms were applied in this study. Logistic Regression and Naïve Bayes were used as baseline models due to their effectiveness in text classification tasks. Support Vector Machine was employed to handle high-dimensional feature spaces, while Decision Tree and Random Forest models were used to capture complex, non-linear relationships within the data. Model performance was evaluated using accuracy, precision, recall, F1-score, and confusion matrix analysis. Comparative evaluation and visualization techniques were used to assess model effectiveness and to examine the impact of sentiment, linguistic, behavioral, and temporal features on rating prediction and review quality assessment.

V. RESULT
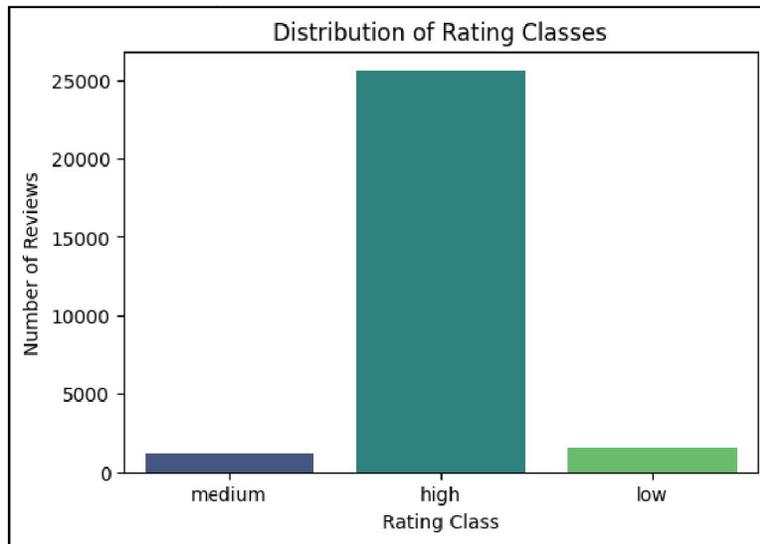
Figure 2: Distribution of Rating Classes

For figure 2, The distribution of rating classes indicates a strong class imbalance in the dataset, with high-rated reviews forming the majority, while medium and low-rated reviews are comparatively fewer. This suggests that customers are generally inclined to provide positive feedback, which is a common characteristic of e-commerce review datasets. The imbalance highlights the importance of using robust classification models capable of handling skewed class distributions.
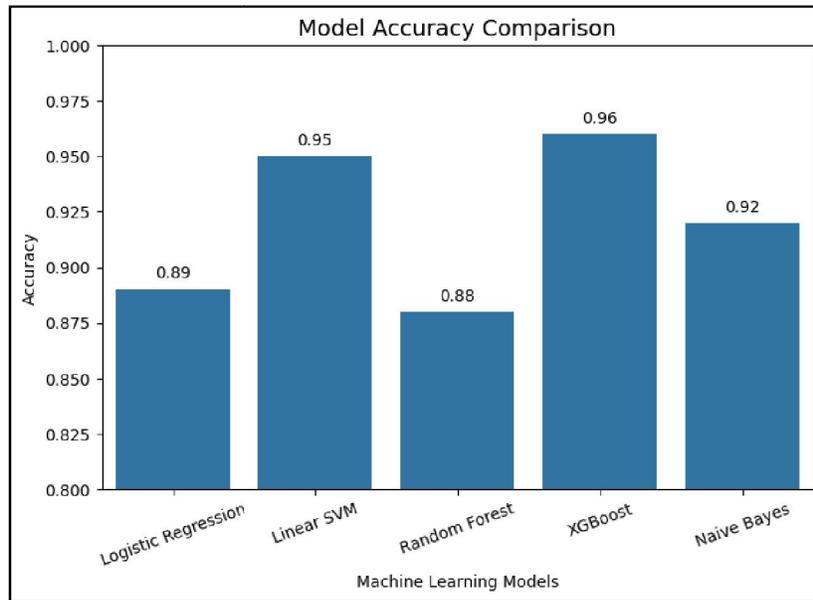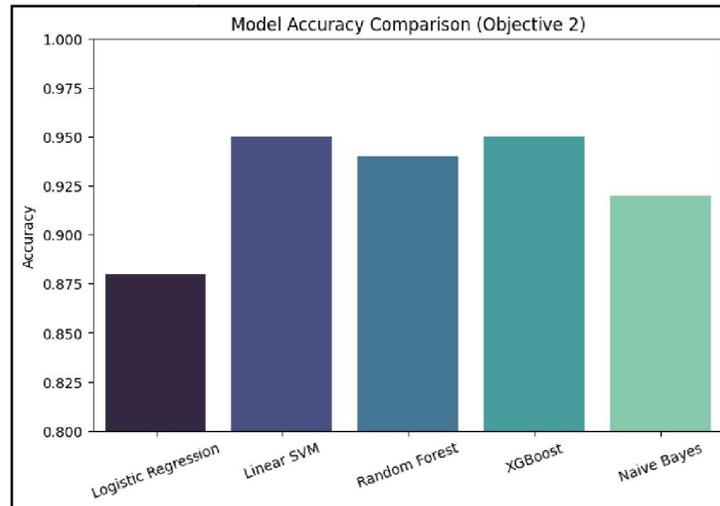

Figure 3: Model Accuracy Comparison (obj-1)

Model	Accuracy	Precision	Recall	F1-Score
Logistic Regression	88%	98%	90%	94%
Linear SVM	95%	98%	98%	98%
Random Forest	89%	97%	94%	91%
XGBoost	94%	94%	99%	97%
Naïve Bayes	92%	92%	99%	96%

Table 1: Model Performance Comparison for Objective 1 (Rating Behavior Prediction)

For figure 3, The model accuracy comparison for rating behavior prediction shows that advanced machine learning models outperform baseline classifiers. XGBoost achieves the highest accuracy, followed closely by Linear SVM, indicating their effectiveness in capturing the relationship between sentiment, linguistic features, and rating classes. Logistic Regression and Random Forest demonstrate comparatively lower accuracy, suggesting limited capability in modeling complex feature interactions.


Figure 4: Model Accuracy Comparison (obj-2)

Model	Accuracy	Precision	Recall	F1-Score
Logistic Regression	88	98%	89%	94%
Linear SVM	95	98%	97%	98%
Random Forest	94	96%	98%	97%
XGBoost	95	96%	99%	97%
Naïve Bayes	92	92%	99%	96%

Table 2: Model Performance Comparison for Objective 2 (Review Helpfulness and Quality Prediction)

For figure 4, review quality and helpfulness prediction, Linear SVM and XGBoost again achieve superior performance, demonstrating consistent robustness across both research objectives. Random Forest also performs competitively. These results confirm that incorporating reviewer patterns and temporal features improves model performance in assessing review quality.
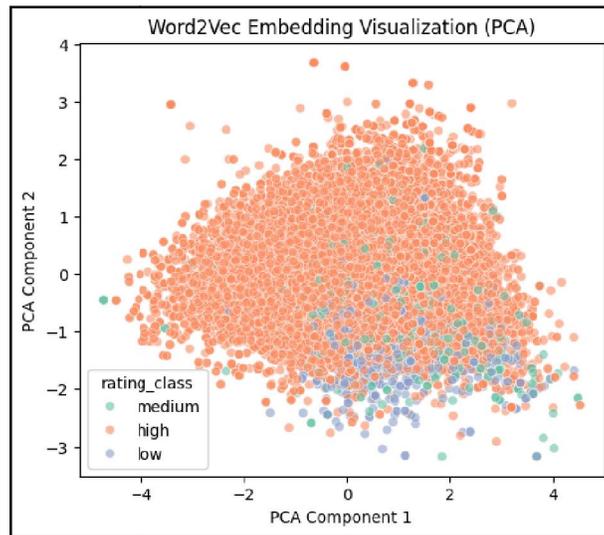
Figure 5: Word2Vec Embedding Visualization (PCA)

For figure 5, The Word2Vec embedding visualization using PCA reveals partial clustering of reviews based on rating classes. High-rated reviews exhibit a denser cluster, while medium and low-rated reviews show greater overlap, indicating shared semantic patterns across different rating levels. This overlap suggests that while semantic embeddings effectively capture contextual meaning, customer sentiment expression often spans multiple rating categories.

VI. MAJOR FINDINGS

The study confirms that linguistic and sentiment-based features play a critical role in influencing customer rating behavior, with positive sentiment, descriptive language, and greater textual richness strongly associated with higher rating classes. Experimental results demonstrate that advanced machine learning models, particularly XGBoost and Linear Support Vector Machine, consistently outperform baseline classifiers across both research objectives. Furthermore, review helpfulness and overall review quality are influenced not only by sentiment polarity but also by review length, reviewer consistency, and temporal factors. Semantic embedding analysis reveals partial clustering of rating classes, highlighting meaningful contextual separation while also indicating overlap in sentiment expression across different rating levels.

VII. RECOMMENDATIONS

Based on the findings, e-commerce platforms should move beyond reliance on star ratings and adopt sentiment-aware, feature-driven review evaluation mechanisms. Highlighting detailed, informative, and balanced reviews can significantly enhance consumer trust and purchasing decisions. Sellers should encourage customers to provide comprehensive feedback rather than short opinion-only responses. From a system design perspective, incorporating reviewer behavior and temporal attributes alongside linguistic and sentiment features can improve review quality assessment. Ensemble-based models such as XGBoost are recommended for deployment due to their superior performance and robustness in handling complex review data.

VIII. CONCLUSION

This research presents a comprehensive analytical framework for understanding customer rating behavior and review quality in e-commerce platforms by integrating sentiment analysis, linguistic feature extraction, and machine learning techniques. The study successfully addresses both research objectives by demonstrating how textual sentiment influences ratings and how reviewer patterns and temporal dynamics affect review helpfulness.

The experimental evaluation highlights the effectiveness of advanced classification models in capturing complex, non-linear relationships within customer review data. The superior performance of ensemble and margin-based models confirms the importance of combining multiple feature dimensions for reliable review analysis. The results further emphasize that review quality cannot be assessed using sentiment alone but requires contextual and behavioral insights. Overall, the study contributes meaningful insights for improving automated review evaluation systems and enhancing decision-making processes in online marketplaces. The proposed approach provides a scalable and adaptable foundation for future research, which may extend this work using deep learning techniques, larger datasets, and cross-domain review analysis to further strengthen predictive accuracy and generalizability.

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