

Mining Beauty Product Reviews: Sentiment, Demographics, and Patterns of Consumer Preference

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Abstract— The goal of this project is to integrate structured product data with unstructured customer reviews to uncover patterns in consumer preferences, analyze the alignment between ratings and sentiments, and build models that explain or predict product success and customer satisfaction.

Keywords— *Exploratory Data Analysis, Sentiment Analysis, Association Mining, Text Mining, Customer Satisfaction, and Data Analysis (keywords)*

I. INTRODUCTION

With the age of consumerism at an all-time high, but the economy in economic decline, it is more important now than ever to understand the product you are looking to buy. Product reviews can make or break a person's mind when it comes to purchasing a product, especially considering there are more than likely multiple similar products that have the same effect. The beauty world is no exception to this. According to McKinsey and Company, the global beauty market reached 450 billion dollars in 2024. Making it one of the biggest markets globally for consumerism. With this comes oversaturation of products, trends, and reviews, but a field of rich content for analysis.

The Beauty Industry provides a particularly rich context for studying consumer feedback. Products in this sector are highly subjective, with satisfaction influenced not only by measurable attributes such as price and availability but also by personal factors such as skin type, tone, and preferences. This gives for deeper reviews with more nuanced meanings, making for a melting pot of analysis and research questions. The dataset “Sephora Products and Skincare Reviews” gives around 8 thousand products and over 1 million user reviews from the Skincare category. This dataset will allow for a deep and meaningful analysis that works towards our goal of the paper.

This paper looks to take a deep dive into these reviews and identify meaningful patterns and relationships. The first method that will be used is Exploratory Data Analysis. It will be used to examine trends, find reviewer demographics, and find patterns in the reviews to find the truth about the product. The next approach that will be utilized is Sentiment Analysis. Sentiment analysis will be applied to customer reviews to assess whether written opinions align with numeric ratings and

recommendation indicators. Finally, association rule mining will be used to identify frequent and co-occurring attributes to see the meaning between product descriptors, customer demographics, and satisfaction outcomes.

The goal of this project is to integrate structured product data with unstructured customer reviews to uncover patterns in consumer preferences, analyze the alignment between ratings and sentiments, and build models that explain or predict product success and customer satisfaction. **By doing so, this research can contribute to understanding the user experience in the beauty sector and demonstrate how Data and Text mining concepts can help in that decision-making.**

II. RELATED WORK

A. *Exploratory Data Analysis and Data Mining on Yelp Restaurant Review*

Text mining and sentiment analysis of consumer reviews have been widely applied in different domains such as restaurants, e-commerce, and mobile applications. These studies demonstrate the importance of analyzing unstructured textual data to uncover patterns in consumer behavior and improve decision-making.

One relevant study is “Exploratory Data Analysis and Data Mining on Yelp Restaurant Review”. The authors applied exploratory data analysis and data mining techniques to the Yelp restaurant review dataset. Their work focused on understanding the distribution of reviews, identifying frequent words across different sentiment categories, and analyzing the relationships between customer ratings and textual feedback. Specifically, they employed methods such as temporal and spatial analysis, Bag-of-Words representation, and topic identification to highlight key features that impact the customer experience.

This research provides a methodological foundation that can be extended to other review datasets. While the Yelp study centered on restaurant services, our project adapts similar techniques to the Sephora Product Reviews dataset, which contains customer opinions on beauty and skincare products. By

leveraging comparable EDA methods, sentiment classification, and keyword analysis, our project aims to extract consumer preferences and identify the factors that drive positive and negative perceptions in the beauty domain.

B. Sentiment Analysis of Beauty Product Applications using the Naïve Bayes Method

Sentiment analysis of product reviews has become an important area of research, as online reviews play a critical role in shaping consumer purchasing behavior. Previous studies have demonstrated the usefulness of machine learning techniques for classifying consumer opinions into positive, negative, or neutral categories.

A recent study by Rambe, Hasibuan, and Dar (2023), titled “Sentiment Analysis of Beauty Product Applications using the Naïve Bayes Method”, applied the Naïve Bayes algorithm to analyze consumer reviews of beauty products. The authors divided reviews into three sentiment classes (positive, negative, and neutral) and combined text preprocessing steps such as TF-IDF feature extraction with classification modeling. Their experiments showed that the Naïve Bayes model achieved an accuracy of 90.08% using a training-test split of 90:10, demonstrating the efficiency of this relatively simple algorithm for sentiment classification tasks. The study also analyzed word frequency distributions, identifying “application,” “product,” and “price” as some of the most frequent terms, thereby highlighting key features influencing consumer sentiment.

This research provides valuable insights for our project, as it illustrates how supervised machine learning methods such as Naïve Bayes can be applied effectively in the beauty product domain. While their study focused on online shopping applications, we extend a similar methodology to the Sephora Product Reviews dataset, which includes both textual reviews and structured product features. By adopting comparable preprocessing techniques and baseline sentiment models, our project aims to validate and expand on their findings while also exploring additional methods such as logistic regression, SVM, or deep learning to improve predictive performance.

C. Customer Perception on Online Cosmetic Product Purchases Using Association Rule Mining Based on Customer Feedback

Understanding customer perception through online feedback has become a critical research direction, particularly in the cosmetics and beauty industry where consumer preferences strongly influence purchasing behavior. Mahesan et al. , in their study “Customer Perception on Online Cosmetic Product Purchases Using Association Rule Mining Based on Customer Feedback”, investigated how consumer reviews can be analyzed to uncover hidden patterns that affect buying decisions. Their work applied association rule mining to identify relationships among customer feedback, product features, and purchasing behavior.

The study demonstrated that association rule mining is effective in highlighting the most influential factors that drive consumer interest and brand loyalty. For example, the authors showed that cosmetic products play a vital role in daily routines, and customer perceptions of attributes such as product quality, price, and brand reputation directly affect purchase plans. By analyzing patterns within consumer feedback, the research

provided actionable insights for companies to improve product marketing strategies and customer retention.

This research is relevant to the project because it emphasizes the importance of analyzing customer feedback in the beauty domain. While Mahesan et al. focused on association rule mining for discovering purchase-related patterns, this project builds on this perspective by performing exploratory data analysis and sentiment analysis on the Sephora Product Reviews dataset. By combining text mining techniques with sentiment classification, our work aims to uncover not only patterns of consumer behavior but also the emotional drivers behind product evaluations, thereby providing a complementary view to the findings of Mahesan et al.

D. Shoes-ACOSI

Aspect-Based Sentiment Analysis (ABSA) traditionally focuses on explicit opinions using the ACOS schema (Pontiki et al., 2014), but struggles with implicit opinions, where sentiment must be inferred (Li et al., 2019). The Shoes-ACOSI dataset (Zhang et al., 2024) extends ABSA to a five-tuple schema (ACOSI) with explicitness labels, highlighting challenges such as long reviews, mixed sentiments, and implicit triggers. Inspired by this framework, our project applies ACOSI to skincare reviews, addressing the gap of implicit opinion extraction in this domain.

E. Relevance to Our Project

These studies collectively establish a strong foundation for research on consumer reviews. The Yelp study provides a methodological framework for EDA, the Naïve Bayes beauty product analysis demonstrates the effectiveness of sentiment classification models, and the association rule mining study emphasizes the role of feedback in shaping purchase decisions. Building upon these works, this project applies EDA, text mining, and sentiment analysis techniques to the Sephora Product Reviews dataset. By combining structured data analysis (e.g., product categories, ratings) with unstructured text mining (e.g., sentiment classification, keyword extraction), this project aims to uncover both the emotional and behavioral drivers of consumer preferences in the beauty industry.

III. PROPOSED APPROACHES

To achieve the goal of analyzing these product reviews, it is important that the right methods of evaluation and review are chosen in order to have successful results.

Three different methods were selected to do this. Exploratory Data Analysis, Sentiment Analysis, and Association Rule Mining.

A. Exploratory Data Analysis

Exploratory Data Analysis (EDA) is used to understand the dataset’s characteristics. The characteristics of this dataset will be presented by summarizing the statistics and using different visual tools.

Using EDA in text analytics will focus on several different aspects, including counts and lengths of the reviews. This will count the words, sentences, and average the length of these.

There is also a term frequency analysis, which will look at the most frequently occurring words and phrases.

The goal of using EDA is to uncover patterns, relationships, and outliers presented in the data. With this information, preparing the data for further analysis and developing a hypothesis will present itself in a more straightforward way.

The majority of the EDA will focus on exploring product categories, regular and discount prices, brand popularity, the impact of different characteristics on price, and ingredient trends. This will be using text mining analysis, comparative analysis, and correlation analysis.

The analysis will be divided into several different sections:

- **Descriptive Statistics of the Structured Data:** Taking the numerical and categorical information, such as prices, average ratings, and product type visualizations, will be created to compare.
- **Exploration of Textual Data:** Focus on word and sentence counts, length, and word frequency to figure out common phrases.
- **Sentiment Rating Alignment:** Compare the alignment between the star ratings (numerical) and the sentiment (textual)
- **Product Feature Trends:** The analysis of the data can be shown through uncovering insights and patterns, such as the development of new products and information. There is also an identification of data quality issues between the product and its ingredients. There is more analysis between brand popularity, price segmentation, and ingredient mentions.

B. Sentiment Analysis

Sentiment Analysis, also known as opinion mining or emotion AI, will be used to focus on the extraction and classification of the opinions in the customer reviews. This method focuses on analyzing and identifying the intent of the customer reviews.

The intent could consist of positive, negative, or neutral sentiments. By applying natural language processing (NLP) techniques, the dataset will be analyzed for emotional tone to compare the tone with the ratings.

The analysis will be divided into several different sections:

- **Polarity Detection:** Determining whether the review falls into a positive, negative, or neutral category
- **Intensity Analysis:** Measure how strong the emotions in the text are.
- **Aspect-Based Sentiment:** Identifying specific features of the product that are associated with the positive, negative, or neutral feedback.
- **Compare Ratings:** Analyze whether the sentiment found in the sentiment testing corresponds with the star rating.

C. Association Rule Mining

Association Rule Mining focuses on large data items and finds relationships between the items. These items could include product features, review terminology, and star ratings. It is often used with a multi-attribute dataset and Market-Based Analysis.

The goal of Association Rule Mining is to discover general patterns that predict success, customer satisfaction, and financial and market trends associated with the product.

The analysis will be divided into several different sections:

- **Frequent Itemset Mining:** Find frequent word combinations. These words could include ingredients or attributes that commonly appeared together in reviews.
- **Rule Generation:** Find and create association rules that explain the connections between the text features and structured data.
- **Rule Reliability:** Using the measures of support, confidence, and lift, determine the strength of the rules. This ensures the meaningfulness of the patterns.
- **Cross-Category Analysis:** Compare rules of different products, brands, and prices to showcase the most satisfied customers and their association.

IV. PLANNED EXPERIMENTS

For the planned experiments, the authors will take the proposed methods and apply them to our data. This study will utilize the large dataset containing over 1.09 million customer reviews across more than 8,000 beauty products. In order to use this data, it must be preprocessed. TO prepare it, duplicate reviews will be removed, timestamps will be standardized, and missing information will be flagged and taken care of. Then normalization of product attributes along with review features. These steps, along with other preprocessing techniques, will produce both structured product-level data and unstructured text features for analysis.

A. Exploratory Data Analysis

EDA is a good first step after preprocessing, as it will establish baseline patterns in the dataset. Product analyses will examine how ratings, review counts, and prices can vary across categories in the beauty industry, such as fragrances, makeup, and skincare. At the review level, EDA will look into whether demographic groups provide systematically different ratings. Correlation Analysis will also be conducted to determine how strongly product attributes such as price and review count correlate with the overall ratings of the product. Together, these analyses will give a foundation to understand which types of products succeed in the marketplace and how certain factors shape success.

B. Sentiment Analysis

The next experiment will use **Sentiment Analysis** to evaluate the relationships between textual sentiments in the reviews and their corresponding star ratings and other indicators. Sentiment scores will be computed for each review and compared against numeric ratings to assess alignment and to identify cases where the written review text does not reflect the corresponding numeric score. Products that have unusually high

ratings but negative textual sentiment, or vice versa, will also be examined to highlight mismatches. These experiments will test the hypothesis that textual sentiment generally aligns with numeric ratings but that meaningful discrepancies exist, particularly in subjective categories such as fragrance.

C. Association Rule Mining

The third set of proposed experiments will be using **Association Rule Mining** to find recurring patterns between product descriptions, customer demographics, and satisfaction outcomes. Reviews will be transformed into transactions by finding keywords and demographic attributes, along with outcomes such as high vs low ratings or recommendation status. After that, association rules will be extracted to find patterns in positive and negative reviews. Other rules may also be researched and evaluated based on support, confidence, and lift, which then will be filtered for stability across categories and time.

Using all three planned experiments, the methods will provide a comprehensive analysis of consumer experience in the beauty industry, specifically Sephora customers and products. This integrated approach is expected to yield insights into both the measurable and emotional drivers of product success, while also identifying discrepancies between numerical ratings and the language of reviews.

PROJECT PROGRESS

V. NARROWING THE DATA

Upon further examination of the data, it was found that there are two separate pieces of our data we have to take into consideration.

A. Product Info

The product info data file has seven hundred and four observations and has twenty-seven features. covering product identifiers, brand details, consumer engagement metrics, pricing, availability, and categorization. While rich in categorical and numerical attributes, some fields (ingredients, pricing variations, descriptions) have significant missing values, which may influence analysis. This will be a challenge that this project will need to address.

B. Reviews

The second half of this project's data is the product reviews. The data in its original form was five files, each containing two hundred and fifty products names and their respective reviews. Each product has multiple reviews, so the dataset is very large, over one million reviews in total. This scale creates several challenges for a text-mining workflow, including data integration issues, quality control, computational constraints, modeling pitfalls, and governance concerns.

C. Selecting our Sample Data

In order to narrow down the project and create a quality assessment, the product requirements had to be narrowed down. By examining the data, it was found that the majority of the reviews given products fell into the skincare quality. Even though the category was narrowed down to skincare, there were still over five hundred thousand reviews, which would not give us a quality assessment.

D. Code Review

The updated Python workflow addressed several challenges brought upon by selecting the sample data, more specifically with the scale and inconsistency of the review data. The code was inputted with the scaled down product reference list, with only our sample data and therefore was relevant to the project scope. It also reads all of the review's files provided in the dataset. It then outputs a .xml file with only the reviews, and their related column information, relevant to our sample data.

E. Data Cleaning and Preprocessing

To prepare this accumulated data the Python script, it also included a series of cleaning and normalization steps. To start off, the product names were standardized. This was achieved by all values converted to lowercase, stripped of punctuation, accents, and extra spaces. This ensured consistency between the reference product list and the review files and reduced false negatives during the matching stage. This also will be beneficial for further analysis stages.

The review was also altered to a form that is easier for the NLPs to understand. HTML tags, non-alphabetical characters, and excess spaces were removed. The text was also converted to lowercase lettering. The titles underwent a similar process to ensure consistency throughout the data.

Demographic variables like skin tone, skin type, hair color, and eye color were normalized into consistent lowercase categories. This was done to reduce fragmentation in the dataset. Numeric fields like ratings and helpfulness scores were cast into numeric types to support statistical aggregation.

Price data was altered to strip the data of any extraneous symbols to just produce a clean numeric column. This makes it easier to analyze trends related to price sensitivity or consumer preference correlations.

Data governance rules were enforced. This was done by removing the empty columns and unnamed metadata fields. Duplicate reviews were also reviewed and removed to avoid bias. With the cleaned text the dataset was further prepared for deeper analysis.

VI. EXPLORATORY DATA ANALYSIS

To begin the project, the first step is to use Exploratory Data Analysis Techniques to gain in-depth knowledge of the complex relationships in the data.

A. Values

The first piece was to evaluate if there are any missing values in the data after combining all of the reviews for the masks together. Using python, it was found that there were some missing values in the data. The most concerning of insight was

that out of 200,000 reviews the helpfulness score feature had 120,920 missing values. This is around 60 percent if all values for this feature are missing. This is problematic because if not addressed these missing values can curve the results and prevent the authors from finding accurate results. To address this issue the authors decided to drop the helpfulness feature and proceed with 19 features. There were also missing features in the 'review_text' and 'cleaned_review_text' columns, but because there were only 182 missing reviews out of the 200,000 observations, the authors decided to drop those with missing text, as the point of this project is to mine the textual part of the reviews.

The last set of missing values that need to be dealt with is in the review title features. The initial missing value script showed that the 'review_title' and 'cleaned_review_title' features also had some missing values with 58,778 titles missing out of the 200,000 reviews. This could be explained by the fact that the title of the review was optional. To solve this the solution was to fill all empty titles with an empty string value of "". This allows for all the rows to be kept while still preserving the accuracy of the data.

As part of the exploratory data analysis (EDA), value counts were used to summarize the frequency distribution of categorical variables, such as skin tone, skin type, hair color, and brand name. This helped identify which categories were most common and whether any levels were underrepresented or imbalanced. For continuous variables such as product price, EDA included examining the overall price range, mean, and spread of values through histograms and summary statistics. These analyses provided insight into the dataset's composition, potential skewness in pricing, and any outliers that might influence later analysis.

B. Trends Over Time

Exploratory data analysis (EDA) was used to examine the distribution of reviews by month. After converting submission timestamps to datetime format, the dataset was grouped by month and year to identify seasonal trends in review activity. The resulting table and visualization showed clear variation in review frequency across months, highlighting potential temporal patterns in consumer engagement.

C. Product and Brand Analysis

By grouping the dataset by 'brand_name' and counting unique 'product_name' values, the analysis identified the brands with the widest product offerings and most reviews. Clinique, Shiseido, and Kiehl's Since 1851 appeared as leading brands in terms of product diversity, suggesting broad market representation and consumer reach.

Next, the relationship between product price and customer rating was explored by grouping reviews by rating and calculating the average 'price_usd' within each group. Results showed that higher-rated products did not necessarily correspond to higher prices, as average prices were relatively consistent across rating levels (around \$59–\$62). This suggests that perceived product quality, as reflected by ratings, may be influenced more by product performance or brand reputation than by price alone.

D. User Demographics

The User demographic information that is available in this dataset gives the unique opportunity to analyze the type of people creating the reviews. This will hopefully help to explain why certain products are getting their respective ratings.

The analysis showed that most reviewers reported *light, fair*, or *light-medium* skin tones, and over half identified as having *combination* skin. The most common hair colors were *brown* and *blonde*, and *brown eyes* were the predominant eye color. A notable share of entries (10–18%) listed demographics as *unknown*, which may reflect optional or incomplete user reporting.

To follow the analysis each feature previously evaluated, the 'skin_tone', 'skin_type', 'hair_color', and 'eye_color' were then grouped by rating to see which types of people gave higher and lower ratings to certain products. Average product ratings were generally consistent across demographic groups. Medium and light skin tones, combination skin, and lighter hair and eye colors showed slightly higher mean ratings, though differences were marginal (within 0.1 rating points). This indicates that reviewer satisfaction did not significantly vary by demographic attributes.

E. Textual Analysis

As part of the textual exploratory data analysis, the average length of user reviews was calculated to assess the amount of written feedback. Additionally, all cleaned review texts were combined and tokenized to identify the most frequently used words across reviews. This analysis provided an initial understanding of reviewer language and key topics prior to any formal text mining or sentiment modeling.

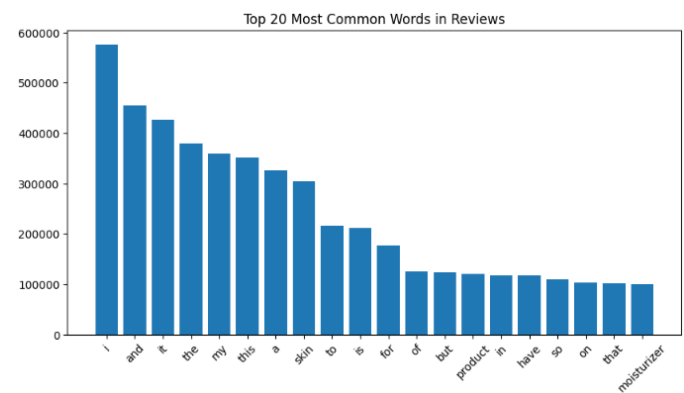


Fig. 1 Top 20 Most Common Words in Reviews

Figure 1 shows a word frequency distribution and bar plot of the top 20 words revealed that common terms such as *and*, *the*, *my*, and *skin* appeared most often, reflecting the conversational and product-focused nature of the dataset.

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