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Uncovering Sustainability Insights from Amazon's Eco-Friendly Product Reviews for Design Optimization

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Abstract: This research investigates consumer reviews of eco-friendly products on Amazon to uncover valuable sustainability insights that can inform design optimization. Using natural language processing (NLP) techniques, including sentiment analysis, key terms extraction, and topic modeling, this research reveals diverse perspectives related to sustainability aspects in eco-friendly products. Innovatively, we integrate the NLP approach with correspondence analysis (CA) to understand consumer sentiments and preferences related to sustainability aspects. Leveraging CA, we visualize the interplay between eco-friendly product features and consumer sentiments, revealing underlying relationships and patterns. The CA biplot showcases the alignment of specific sustainability attributes with consumer satisfaction, highlighting which sustainability aspects hold greater influence over overall product ratings. As sustainability becomes an increasingly crucial aspect of consumer choices, our paper emphasizes the significance of a multidimensional approach that embraces both qualitative and quantitative insights. By blending CA with consumer reviews, we equip designers and stakeholders with an innovative and comprehensive toolkit to enhance sustainable design practices, paving the way for more informed and effective product development strategies in the realm of eco-friendliness.

Keywords: sustainable product design; eco-friendly product; consumer review; natural language processing; correspondence analysis

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1. Introduction

In recent years, environmental concerns have gained more attention from consumers in line with the increasing importance of sustainability. As a result, the demand for eco-friendly products is rising [1]. The consumer midshift toward the sustainability aspect of products that they consume is not merely a temporary trend: it shows an essential move toward ensuring long-term environmental well-being. Several studies demonstrate that environmental impact is related to unsustainable consumer behavior and highlight some benefits of shifting to eco-friendly products [2–4]. Therefore, sustainability and eco-friendly concepts in product design and development raised significant concerns from both consumers and manufacturers.

E-commerce platforms nowadays play a significant role in promoting sustainable yet eco-friendly products due to their accessibility [5]. Recently, many products displayed on e-commerce platforms are labeled as eco-friendly to gain interest from environmentally conscious consumers [6]. This eco-friendly branding also goes beyond the label: there are various forms, such as sustainable packaging to compostable materials. While such branding strategies are commendable and in line with the growing demand for sustainable products, there is discussion related to the authentic impact of those eco-friendly labels [7]. Several investigations reveal that those labels genuinely represent the products, but others argue that they might be susceptible to greenwashing [8,9]. Greenwashing itself is a kind of

phenomenon where products are falsely marketed as environmentally friendly. Therefore, the consumer perception toward the claimed eco-friendly product that they used remains an area that needs comprehensive examination [10].

This study aims to examine the consumer perception of sustainable and eco-friendly product labels on Amazon. As one of the e-commerce giants, Amazon introduced a dedicated "Climate Pledge Friendly" badge for products that are verified as eco-friendly and sustainable. By analyzing the description of those products and associated consumer reviews, we aim to reveal how those eco-friendly labels shape the narratives of sustainable and eco-friendly products available on e-commerce. We build upon a hypothesis that consumer reviews, as available on platforms like Amazon, serve as a rich source of information, offering insights into customer preferences and feedback on sustainable products [11–13]. For this objective, we used natural language processing (NLP) techniques such as key terms extraction and sentiment analysis to extract meaningful insight from large amounts of textual data in the form of product descriptions and consumer reviews. In the case of consumer review analysis, NLP is a well-known methodology that can unveil information related to consumer preference, sentiments, and concerns related to certain products and services [14,15]. While there are various methodologies available for data analysis, such as Bayesian methods, which are adept in probabilistic modeling and handling dynamic datasets [16,17], NLP is selected for its unparalleled efficiency in processing unstructured textual data. NLP's capability to extract key terms, comprehend contextual nuances, and conduct sentiment analysis makes it particularly suitable for deciphering the intricacies of consumer perceptions and attitudes directly from their narratives.

Recently, there have been numerous studies that utilized NLP to analyze user or customer reviews to gain insight into their experience and satisfaction with using certain products and services [18,19]. However, specific studies related to consumer reviews of sustainable or eco-friendly products are still rare. Moreover, those NLP-centric methods are used primarily for sentiment analysis and topic modeling, which might not fully capture the intricate relationship between product attributes and consumer satisfaction. As a result, the interpretation of consumer preferences on such products is merely on the surface level, not delving deep into more detailed insight into the relation of consumer satisfaction to specified features of the product. Therefore, one of the objectives of this research is to employ the NLP technique together with correspondence analysis (CA). CA has been recognized as an effective method for visualizing relationships and patterns in categorical data [20]. While it is relatively rare in the literature, some studies have effectively combined NLP with correspondence analysis to extract deeper insights from textual data and visualize intricate relationships [21,22]. Therefore, in our case, combining NLP and CA can provide a more comprehensive understanding of how sustainability or eco-friendly attributes of the products relate to user satisfaction aspects.

One of the contributions of this work is the addition of consumer review studies to the existing literature by integrating NLP and CA. While previous studies often used NLP as the main quantitative method, our proposed approach synergized NLP and CA to offer a more comprehensive understanding of consumer preference and its relationship to product features, specifically the eco-friendly attributes of the products. By doing so, this study also provides a more comprehensive examination of product descriptions and their corresponding consumer reviews on the sustainability features of the products. As a result, this study provides stakeholders with insight that can be instrumental in optimizing the design and development of eco-friendly products.

2. Materials and Methods

This study employed a set of technical approaches to analyze and visualize consumer sentiment and preferences associated with eco-friendly products on Amazon. The main approach in this work was the collection and analysis of product descriptions and consumer reviews using advanced NLP and CA techniques. This section delineates the data collection

process, criteria for selection, and data processing approach methods based on NLP and CA to extract and interpret the textual data contained within consumer reviews.

In this work, NLP is employed to distill and analyze the vast textual data on product descriptions and consumer reviews. The objective of implementing NLP is to systematically unveil the implicit preferences and sentiments of consumers regarding eco-friendly products listed on Amazon. Following the NLP, CA was then used to systematically measure how those consumer preferences related to their satisfaction, which was reflected in the sentiments. This sub-section will outline several technical approaches regarding text data processing using NLP. We start with the pre-processing of the text data, followed by key terms extraction, which represents consumer preferences. Afterward, another part of NLP tasks sentiment analysis and sentiment terms extraction will be explained. Lastly, the approach of CA will also be outlined comprehensively.

2.1. Data Collection and Preparation

Data for this study were collected from an Amazon.com search page with "eco-friendly product" as the initial key terms. For more specific and verified results, the data collection of this work targeted products that were tagged with the "Climate Pledge Friendly" badge, which is used by Amazon to signify products that meet various sustainability certifications and eco-friendly standards. Therefore, this badge indicates that products have been assessed to ensure that they support Amazon's commitment to preserving the environment. The inclusion of the "Climate Pledge Friendly" badge in our data selection process was instrumental in mitigating the risk of greenwashing. This badge, by necessitating adherence to specific sustainability certifications and standards, provides a layer of verification that goes beyond mere self-proclaimed eco-friendly claims, thereby ensuring a higher likelihood that the products analyzed in our study genuinely contribute to sustainability.

After the data collection process, the resulting information from the search query was then extracted using a custom-built web scraping tool. The tool was programmed using Python to collect the following information for each product:

- Product Identifiers: The unique ASIN (Amazon Standard Identification Number) (https://affiliate-program.amazon.in/resource-center/asin-amazon, accessed on 16 December 2023) and product name.
- Product Descriptions: The text describing the product features, including any mentions of eco-friendly attributes, the kind of material used, and sustainability certifications.
- Consumer Reviews: All available consumer reviews of the products, including the title, body, star rating, and date of the review.

In order to meet the terms of service to ensure ethical data collection practices, the tool was designed to comply with Amazon's robots.txt file (https://www.amazon.com/robots.txt, accessed on 7 September 2023). Additionally, the scraping tool was set to include a delay between requests to Amazon's servers to prevent any disruptions to their service, in line with ethical web-scraping practices. Upon the collection of the data, the selection of the product data, which includes analysis, should fulfill certain criteria as follows:

- Review Count: This work only includes the products with a minimum of 10 consumer reviews to ensure that there were sufficient data for robust analysis.
- Time Frame: Reviews collected were limited to those posted within the last two years to ensure that the relevance of consumer sentiments and preferences is contingent on current sustainability trends.
- Language: Only reviews written in English were included to maintain consistency in language for the NLP analysis.

Following the data collection and respecting the selection criteria, the dataset consisted of 2.059 product entries and 54.445 consumer reviews, which formed the basis for the analysis tasks of this work. Afterward, to ensure the reliability of analysis results and provide computational tractability of our data, the data were subjected to a set of pre-processing procedures to remove irrelevant content to prepare the dataset for NLP analysis.

This included the removal of non-alphanumeric characters, the removal of stop words to eliminate common but irrelevant words, and stemming to simplify various word forms under a common standard.

2.2. Key Terms Extraction

We employed a two-step approach regarding eco-friendly-related key terms extraction. At first, we use part-of-speech (POS) tagging to identify and retain the nouns, adjectives, and proper nouns as they often are a key to understanding the main topic within a text/sentence. After POS tagging, the final selection of the key terms extraction was performed by using TF-IDF (term frequency–inverse document frequency). TF-IDF is a kind of numerical statistic reflecting how a word is to a document in a collection or corpus. POS tagging involves the identification of words' roles within sentences, such as nouns, verbs, adjectives, etc. By focusing on nouns and adjectives through POS tagging, we specifically targeted those words most likely to represent key aspects and features of eco-friendly products. Subsequently, TF-IDF was employed to evaluate the importance of these words within the corpus. This method calculates a weight for each word, signifying its relevance in a document relative to its frequency across the entire dataset.

By integrating POS tagging and TF-IDF, we were able to effectively isolate and emphasize the terms most central to our analysis, ensuring a nuanced and targeted extraction of key terms that reflect consumer priorities and perceptions in the realm of sustainable products. In the following outline, the fundamental concepts of POS tagging and TF-IDF will be briefly explained.

2.2.1. Part-of-Speech (POS) Tagging

POS tagging aims to unveil the structure of any given sentence. Therefore, by using POS tagging, a certain word within a sentence can be identified as nouns (things), verbs (actions), adjectives (descriptions), and so on [23]. Understanding the sentence structure is very important for increasing the accuracy of information extraction [24]. In a computational approach like NLP, the task of part-of-speech (POS) tagging is to programmatically assign labels on words in a sentence to show their grammatical role. The common technical approaches to this task use algorithms or machine learning models that have been trained on a tagged corpus to predict the POS of each word [25]. These models learn to predict the most likely label for each word in new sentences.

To train a machine learning model for the POS tagging task, the data for POS tagging can be framed as a sequence of words $W = \{w_1, w_2, \ldots, w_n\}$. Afterward, another sequence containing a tag $T = \{t_1, t_2, \ldots, t_n\}$ is assigned corresponding to W. In this context, W and T represent a list of words and corresponding tags that occurred in certain sentences. The goal of the POS tagging model is to predict the right sequence of tags T given a sequence of words W. That work can be considered as maximizing the probability $P(T|W)$, which is the conditional probability of a tag sequence T given the word sequence W. Additionally, each tag is a label that denotes the grammatical role of a word in a sentence, such as noun (NN), verb (VB), adjective (JJ), etc.

There are various technical approaches to training the POS-tagged dataset, such as hidden Markov models (HMMs), conditional random fields (CRFs), or, more recently, deep learning models [26–28]. Nevertheless, for practical purposes, in this work, we use a pre-trained model available on SpaCy that trained over a large amount of English text.

2.2.2. Term Frequency-Inverse Document Frequency (TF-IDF)

After POS tagging, we proceeded to identify the most relevant terms using TF-IDF, which is a numerical statistic intended to reflect how important a word is to a document in a collection or corpus. In this research, the TF-IDF was used as a technical approach to extract the significant words that become candidate key terms from the product description and consumer review as well. *TF-IDF* compares the frequency of terms in a single product description or consumer review to their frequency across the entire dataset.

The *TF-IDF* consists of two parts, the term frequency (*TF*) and inverse document frequency (*IDF*). The TF (term frequency) and IDF (inverse document frequency) of TF-IDF are two different measurements that can be calculated separately. TF is a measure of the relative occurrence of a term within a document as depicted in Equation (1), where t denotes a specified term in a single document d and f represents the occurrence number of term t in a single document d [29]. The denominator in Equation (1) then denotes the total number of all terms in a single document d. Apart from *TF*, the *IDF* part measures the informativeness or rarity of a term across the document corpus as depicted in Equation (2) [30]. In Equation (2), N depicts the number of documents within the entire corpus dataset, while D denotes the number of documents d that contain terms t.

$$TF(t,\ d) = \frac{f_{t,d}}{\sum_{t' \in\ d} f_{t',\ d}} \tag{1}$$

$$IDF(t, D) = \log \frac{N}{1 + |\{d \in D\ : t \in d\}|} \tag{2}$$

$$TFIDF(t, d, D) = TF(t, d) \times IDF(t,\ D) \tag{3}$$

From Equations (1) and (2), the TF-IDF score is derived by multiplying *TF* and *IDF* as shown in Equation (3). Terms with higher TF-IDF scores are considered more significant within the context of the document. Therefore, keywords are often extracted based on their elevated TF-IDF scores, indicating their prominence within a particular document while exhibiting relative rarity across the entire corpus. Hence, the extraction of key terms using TF-IDF enables the identification of terms that contribute significantly to the overall meaning of the content reflected by either product descriptions or consumer reviews.

2.3. Sentiment Analysis

Sentiment analysis, at its core, involves the computational identification and categorization of opinions expressed in text data, aiming to determine the writer's attitude toward particular topics or the overall tonality of the text. In our case, this involved analyzing consumer reviews to classify sentiments as positive, negative, or neutral. This classification was achieved through a machine learning algorithm trained to recognize sentiment-indicative words and phrases within the text. By evaluating the frequency and context of these sentiment markers, the algorithm provided a sentiment score for each review, offering a foundational understanding of consumer attitudes toward eco-friendly products.

In this work, the specified category of sentiment analysis named aspect-based sentiment analysis (ABSA) was employed for more granular analysis. ABSA is a subfield of sentiment analysis that focuses on identifying the sentiment toward specific aspects within a text. Instead of classifying the overall sentiment of a text, ABSA reveals more fine-grained sentiments associated with certain features or aspects of a product mentioned in the text [31]. In this study, ABSA was utilized to extract consumer sentiments related to various aspects of eco-friendly products reviewed on Amazon. This approach enabled us to pinpoint which product features correlate with certain categories of customer satisfaction.

In this work, the technical approach for implementing ABSA can be decomposed into the three following steps:

- Aspect Identification: Each review is parsed to detect and extract aspects related to eco-friendly attributes of products. Since this work performed key terms extraction on the previous steps, the identified key terms of eco-friendly-related words were then used as aspects for aspect-based sentiment analysis.
- Sentiment Detection: To determine the sentiment around the identified aspects, we then used a pre-defined term-based sentiment model. Specifically, we implemented sentiment detection using the Valence Aware Dictionary for Sentiment Reasoning (VADER) framework, which has already been implemented in SpaCy. VADER is a

kind of lexicon- and rule-based sentiment analysis tool that is specifically attuned to sentiments expressed in social media [32]. VADER utilizes a combination of a sentiment lexicon, which is a list of lexical features (e.g., words) that are generally labeled according to their semantic orientation as either positive or negative.

- Sentiment Quantification: The sentiment scores for each aspect are quantified based on their semantic orientation and intensity, which are inferred from the text. VADER assigns each text a compound score that aggregates the cumulative sentiment of all words in the text, normalized between −1 (most negative) and +1 (most positive).

To briefly define how VADER works, first let $S = \{s_1, s_2, \ldots, s_n\}$ be the set of sentences in a review, and $A = \{a_1, a_2, \ldots . a_m\}$ be the set of defined aspects. For each aspect a_j, we then determine a sentiment score c_j using the compound score from VADER calculated by following Equation (4) [32].

$$c_J = \sum_{i=1}^{n} Valence(s_i) \times 1_{a_j \in s_i} \quad (4)$$

In Equation (4), $Valence(s_i)$ is defined as the normalized sentiment valence for sentence i, and $1_{a_j \in s_i}$ is a function that yields value 1 if the aspect a_j is present in a sentence s_i and 0 if otherwise. Then, the sentiment score for each aspect c_J represents the aggregated sentiment toward that particular aspect across all sentences in the review. These scores are then used to infer the overall consumer sentiment toward specific sustainability attributes of eco-friendly products.

2.4. Correspondence Analysis

Correspondence analysis (CA) is a way to visualize the relationship between two categorical variables in a dataset. CA employed a multivariate graphical technique designed to reveal associations and visualize the relationships in two-dimensional space [33]. The example utilization of CA in this research is for creating a map that shows what product sustainability features and customer experience aspects are expressed in customer reviews. By plotting this information, CA helps us to see which aspects of eco-friendly products contribute to a specific type of customer satisfaction.

In this study, we used CA to draw connections between specific eco-friendly terms mentioned in product descriptions on Amazon and the user satisfaction aspects discovered in user reviews. The main ingredient of CA is a contingency matrix as illustrated in Figure 1. The matrix in Figure 1 provides an example of how the presence or absence of eco-friendly attributes in certain products crossed with consumer satisfaction categories from reviews. In Figure 1, ECA represents the first categorical data—for example, the eco-friendly attributes of the product—while USA represents the user satisfaction aspects. The frequency of ECA mentioned on the consumer reviews that emphasize certain user satisfaction aspects is then reflected as the cell values on CA matrix depicted in Figure 1.

	USA_1	USA_2	....	.....	USA_m
ECA_1	$cof_{1,1}$	$cof_{1,2}$	.....	.....	$cof_{1,m}$
ECA_2	$cof_{2,1}$	$cof_{2,2}$	.....	.....	$cof_{2,m}$
ECA_3	$cof_{3,1}$	$cof_{3,2}$	.....	.....	$cof_{3,m}$
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	
ECA_n	$cof_{n,1}$	$cof_{n,2}$	.....	.....	$cof_{n,m}$

Figure 1. The example of a contingency matrix for correspondence analysis.

In this study, we programmatically created the contingency matrix from our data similar to Figure 1. The process starts by counting how often each combination of product feature and sentiment occurs, forming a matrix. Once the contingency matrix is provided, the next process in CA is to adjust those frequency counts into proportions. Upon the adjustments, each cell of the contingency table then contains proportions representing the relative occurrence of the attribute–aspects pairing. Afterward, to unveil the pattern, which can be easily visualized on a biplot diagram, a singular value decomposition (SVD) was applied to the proportion matrix. The following Equation (5) describes the common SVD formulation for CA [34]. In Equation (5), P is the decomposition of the proportion matrix, which yields an essential correlation pattern in matrices U_k and V_k^T and their strength, which is reflected on matrix D_k.

$$P \approx U_k D_k V_k^T \tag{5}$$

The outputs of SVD are then used to generate a perceptual map to depict the relationship between the eco-friendly attributes and user satisfaction aspects on a biplot diagram. On the perceptual map, the proximity of points on this biplot indicates the strength of association [35]. Through this approach, CA helps us to create an intuitive map that reveals which eco-friendly features are most frequently mentioned in the context of satisfaction aspects. This visual representation is instrumental in pinpointing which sustainable practices are most valued in certain aspects of consumer satisfaction. Additionally, we utilized CA to unveil the relationship of eco-friendly-related terms to product categories and material used, respectively.

3. Results

3.1. Product Analysis

This section presents a detailed analysis of product descriptions sourced from Amazon's eco-friendly list. The objective was to identify the most common product categories, items, and associated key terms that emphasize eco-friendliness and sustainability. Additionally, we examined the materials commonly mentioned in these products to determine sustainable material choices in the market.

3.1.1. Product Category

Figure 2 depicts the distribution of eco-friendly products across various categories on Amazon. This diagram illustrates the disparities in the product category and highlights the areas for eco-friendly product expansion. The high frequency of eco-friendly products in the "Health & Household" categories shows a burgeoning consumer concern for sustainability within personal and household care products that they use on a daily basis. Meanwhile, the "Home & Kitchen" category, which is also gaining high popularity for eco-friendly products, indicates the increased consumer awareness and demand for eco-conscious home solutions. In contrast, the limited eco-friendly options in "Industrial & Scientific" and "Grocery & Gourmet Food" might hint at market segments or areas where sustainable innovations are still in the initial stage.

Figure 2 depicts a macro perspective on the categories of products that are popularly labeled as eco-friendly. However, as consumer preferences evolve specifically in recent years, it is essential to give more detailed information about the items within those categories that resonate with the eco-conscious mindset. Therefore, Figure 3 provides a spotlight on the product items that are most frequently associated with sustainability claims. The information depicted in Figure 2 allows us to pinpoint the product items in which sustainable innovation is dominantly applied and gains the most interest from consumers. At the same time, this information offers a more comprehensive view of the eco-friendly product landscape on Amazon.

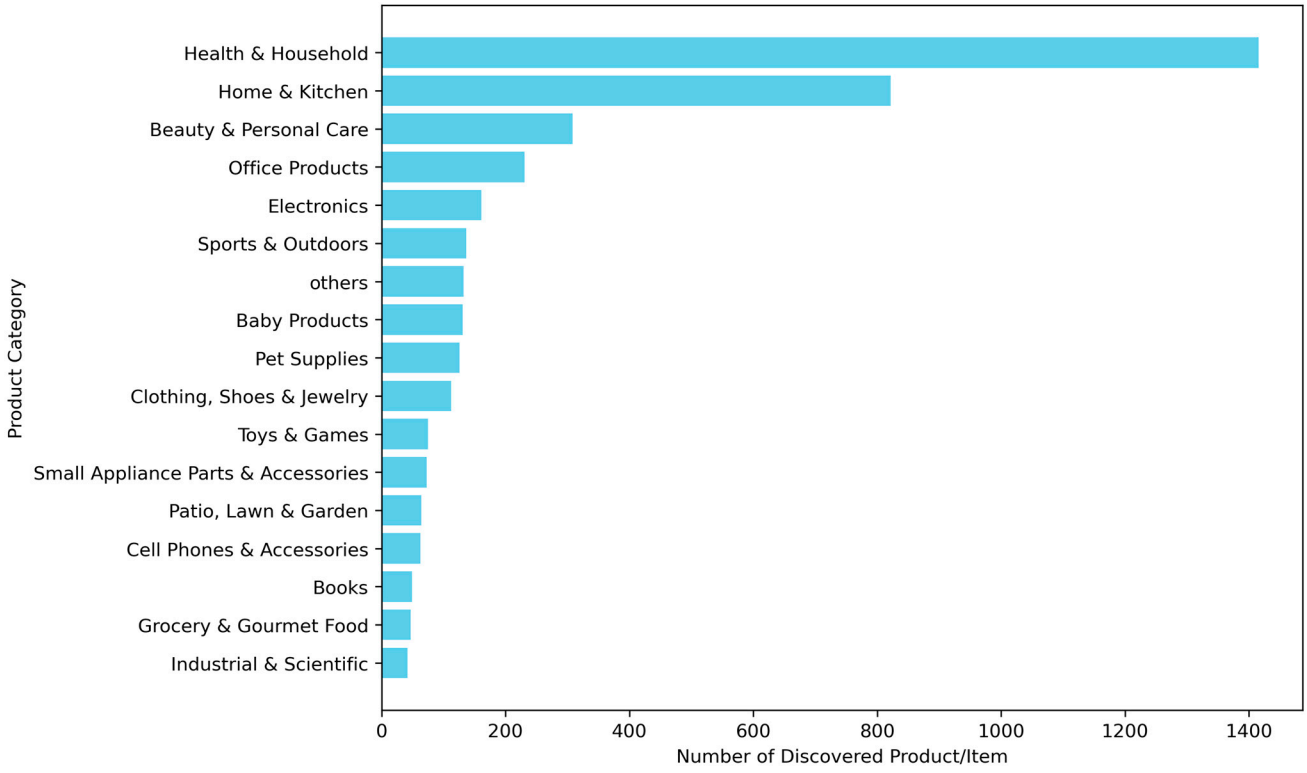


Figure 2. Distribution of eco-friendly products across various categories on Amazon.



Figure 3. Word cloud of common product items labeled as eco-friendly on Amazon.

Figure 3 complements the previous Figure 1 by giving more specific information. The prominence of terms such as "Plates", "Cups", "Bowls", "Straws", and "Sponges" shows a significant consumer focus on everyday household items. The frequent use of those items in everyday activities makes those items popular and a main target of eco-friendly branding. Afterward, the appearance of terms such as "Compost", "Reusable Filters", "Cleaning Cloths", and "Reusable Grocery Bags" addresses the inclination toward reusable solutions to reduce single-use products and minimize waste. On the other hand, the smaller terms highlight niche areas where there are eco-friendly alternatives that might not yet be popular, where these options exist but might not yet dominate the market.

3.1.2. Sustainability Terms

Following the categorization of eco-friendly products, we then thoroughly examined the terms used by manufacturers or sellers on Amazon to define sustainable products. By extracting those terms, we can identify the prevalent themes and characteristics of eco-friendly products available on Amazon. Figure 4 shows that "eco-friendly" is the most commonly used term, indicating its popularity in identifying sustainable products. The terms "natural", "compostable", and "biodegradable" address that organic origins and minimal environmental impact also attract much attention. Product longevity is represented by the term "durable", which is also frequently used to address sustainability issues. It makes sense that long-life products would have minimal impact on the environment. Afterward, terms such as "certified" and "bpa free" highlight the importance of verified sustainability claims and health-conscious choices. On the other hand, some terms are not directly associated with eco-friendliness, such as "microwave safe" and "heat resistant". Nevertheless, they can be related to the durability and reusability of the products. Overall, Figure 4 depicts the variation in and frequency of terms to illustrate sustainability attributes to promote eco-friendly product listings on Amazon.

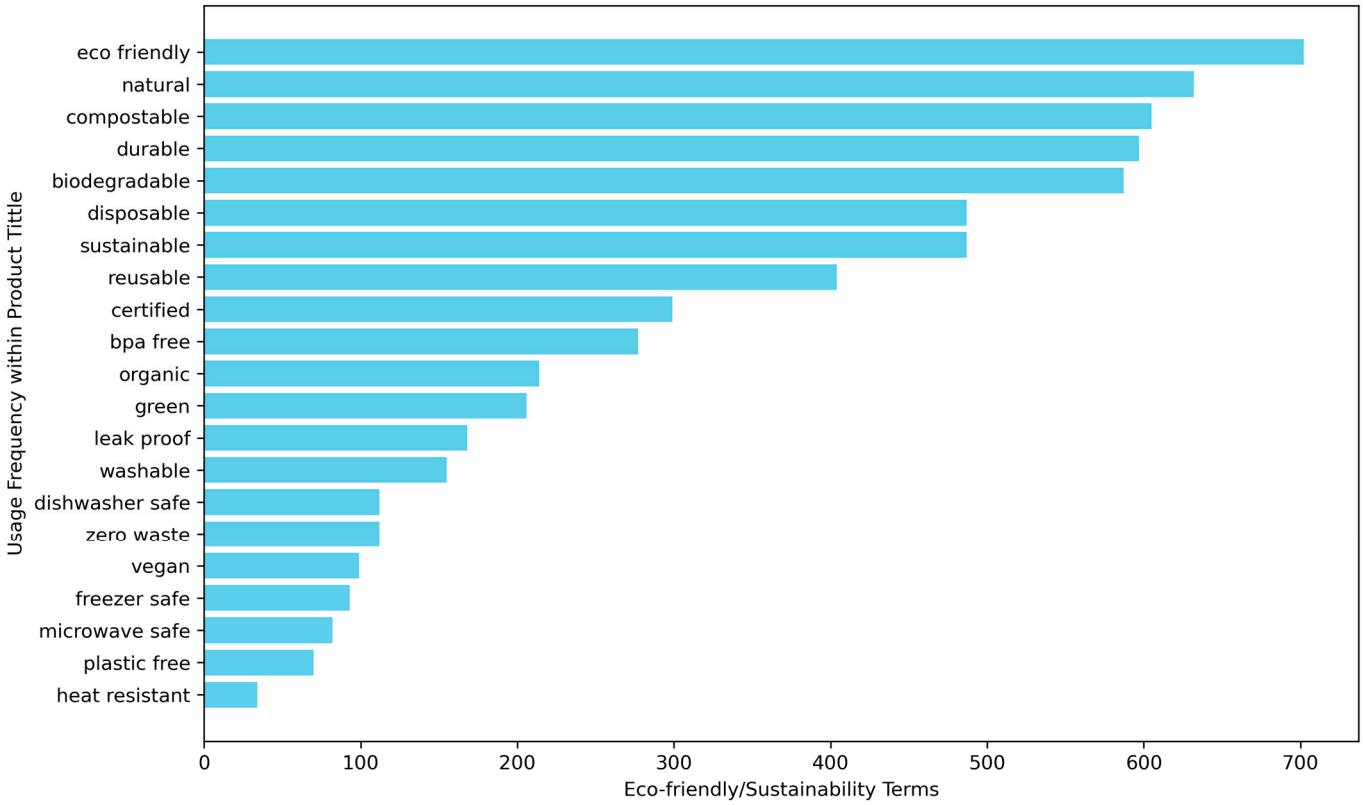


Figure 4. Frequency of eco-friendly and sustainability terms in product descriptions.

The prevalence of terms such as "eco-friendly" and "natural" shows the generic perception toward broader sustainability-claimed products. However, in Figure 4, as we move down the list, there are terms such as "biodegradable", "disposable", "reusable", and "bpa free". Those actionable terms suggest products with more concrete and verifiable eco-friendly attributes that might also attract consumers. On the other hand, the appearance of terms related to product functionality, such as "leak-proof", "microwave safe", "freezer safe", or "dishwasher safe", address the necessity of balancing practicality with sustainability. Hence, manufacturers are not only emphasizing the eco-friendly nature of their products but also ensuring that they meet the daily needs and expectations of the consumers. In addition to Figure 4, the following Table 1 provides an overview of the extracted sustainability attributes.

Table 1. Overview of the extracted sustainable attributes.

Attributes	Definitions
Eco-friendly	Products or practices that are not harmful to the environment.
Natural	Products made from natural ingredients or materials, without artificial additives or processes.
Compostable	Products that can break down into non-toxic components in compost conditions, contributing to soil health.
Durable	Products that are long-lasting and do not need to be replaced frequently, reducing waste and consumption.
Biodegradable	Materials that can be broken down by microorganisms over time, reducing pollution.
Disposable	Products intended for single use before being discarded, where the sustainability focus may be on the materials used and the product's end-of-life environmental impact.
Sustainable	Practices or products that meet present needs without compromising the ability of future generations to meet their needs.
Reusable	Products that can be used multiple times for the same or different purposes, reducing the need for single-use items.
Certified	Products that have been awarded a certification from recognized bodies, indicating that they meet certain sustainability standards.
BPA-free	Products made without bisphenol A, a chemical found in some plastics that can have adverse health effects.
Organic	Typically refers to products made from materials grown without the use of synthetic pesticides, fertilizers, or genetically modified organisms.
Green	A general term often used to describe products or actions that are environmentally friendly.
Leak-proof	Products designed to prevent the escape of liquids or gases, which can contribute to durability and reusability.
Washable	Products that can be cleaned and reused, thereby reducing waste.
Dishwasher-safe	Items that can withstand the environment inside a dishwasher, indicating durability and reusability.
Zero-waste	A principle that encourages the redesign of resource life cycles so that all products are reused, with no trash sent to landfills or incinerators.
Vegan	Products that do not contain animal ingredients or animal-derived ingredients and are often associated with ethical and environmental sustainability.
Freezer-safe	Products that can withstand freezing temperatures without degrading in quality, allowing for a longer preservation of food and reducing waste.
Microwave-safe	Products that can be used in a microwave without melting or releasing harmful chemicals, indicating convenience and reusability.
Plastic-free	Products that do not contain plastic, reducing reliance on fossil fuels and potential for pollution.
Heat-resistant	Products that can resist damage from heat, contributing to their durability and lifespan.

To complement the sustainability terms, we then examined the common material used for sustainability claims. The material used for the product is essential to the sustainability claims since the raw materials are one of the most significant aspects of a product's environmental impact. Figure 5 shows the frequency of various materials found in eco-friendly product listings. As can be seen in Figure 5, "paper" emerges as the most frequently mentioned material, indicating its widespread adoption as an eco-friendly alternative. Afterward, "plant" and "bamboo", as the common raw materials for paper, appear just before paper in terms of frequency. The prominence of bamboo as a plant-based material alongside "wood", "cotton", and "palm" addresses the commonly growing preference for compostable or biodegradable material. Bamboo and other plant-based materials are known for their rapid growth rates and lower environmental footprints. Therefore, with their inherent eco-friendly qualities, those materials have gained traction in recent years from product developers. Other materials such as "glass" and "stainless steel" also find notable mentions, which indicates a diverse range of sustainable materials catering to different product needs. Materials such as glass and stainless steel, although not biodegradable, can be repeatedly recycled without a loss of quality, contributing to their popularity in sustainable product categories.

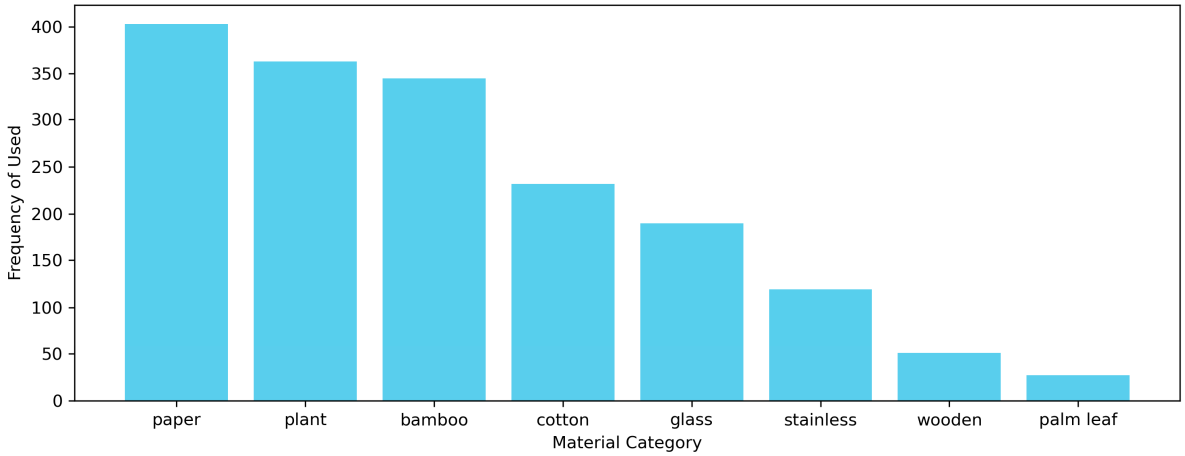


Figure 5. Distribution of materials used in products claimed as eco-friendly on Amazon.

While Figures 3–5 depict product items, eco-friendly terms, and materials used, respectively, Figure 6 tailors them together in a single frame to provide a rich visual representation. Figure 6 displays the combination of those elements—product items, materials, and their associated eco-friendly claims—to encapsulate a more holistic view of how eco-friendly products are being presented in the marketplace. The word cloud depicted in Figure 5 illustrates a more comprehensive reflection of the market's direction toward eco-friendly products and showcases the convergence of product types, materials, and eco-friendly claims. The prominence of terms such as "disposable paper", "biodegradable paper", and "compostable paper" addresses the widespread acceptance of these products and materials in the eco-friendly niche. The strong emphasis on "plates" products addresses the strong inclination toward sustainable dining and kitchenware. On a subtler note, the word cloud also reveals some lesser-highlighted terms, which shows the diversity of eco-friendly products available.

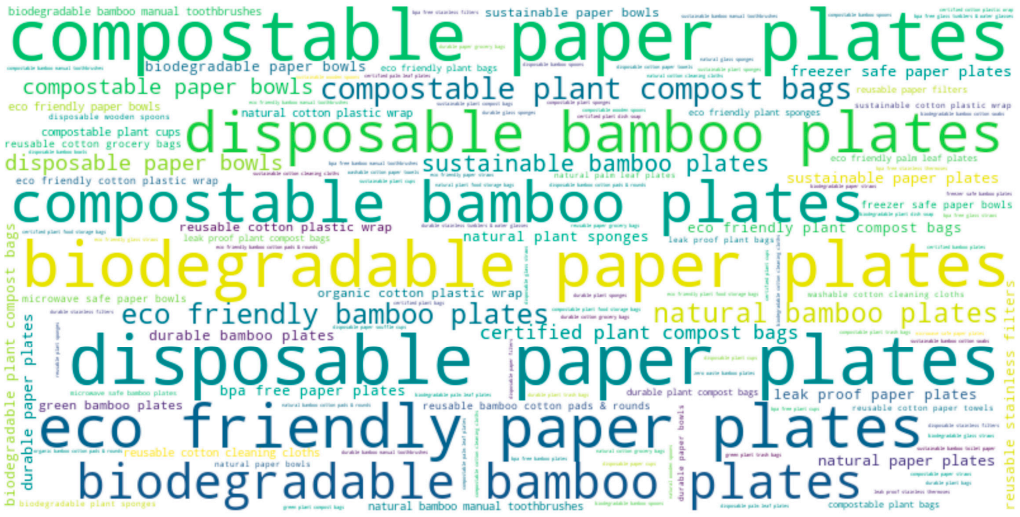


Figure 6. Word cloud representation of eco-friendly product concepts combining items, materials, and sustainability claims.

3.1.3. Perceptual Map

The perceptual maps provided in this section were derived from correspondence analysis. This map serves as a methodological approach to understanding the associations between distinct aspects of the eco-friendly product outlined in the previous sub-sections. The subsequent figures depict the relationship between sustainability concepts and two fun-

damental components: the product category and the material composition of the product. By mapping these correlations, the goal is to discern the patterns and insights regarding consumer understanding and preference for eco-friendly products. This examination can reveal how sustainability concepts are perceived in relation to product category and material, and how those concepts are related to each other.

The first perceptual map is depicted in Figure 7 to illustrate the relationship between various sustainability terms and product categories. The Figure 7 perceptual map shows the clear separation between terms surrounding certain product categories. Terms such as "leak proof" are closer to "Pet Supplies", which are far different in the context of product features from those such as "vegan" or "organic", which resonate with "Beauty and Personal Care". This separation addresses the different sustainability priorities of the distinct product category. In contrast, categories such as "Beauty & Personal Care" and "Clothing, Shoes, & Jewelry" are spatially closer to each other compared to "Industrial & Scientific". This proximity might reflect underlying similarities in consumer expectations or marketing narratives for these sectors when it comes to eco-friendly labels.

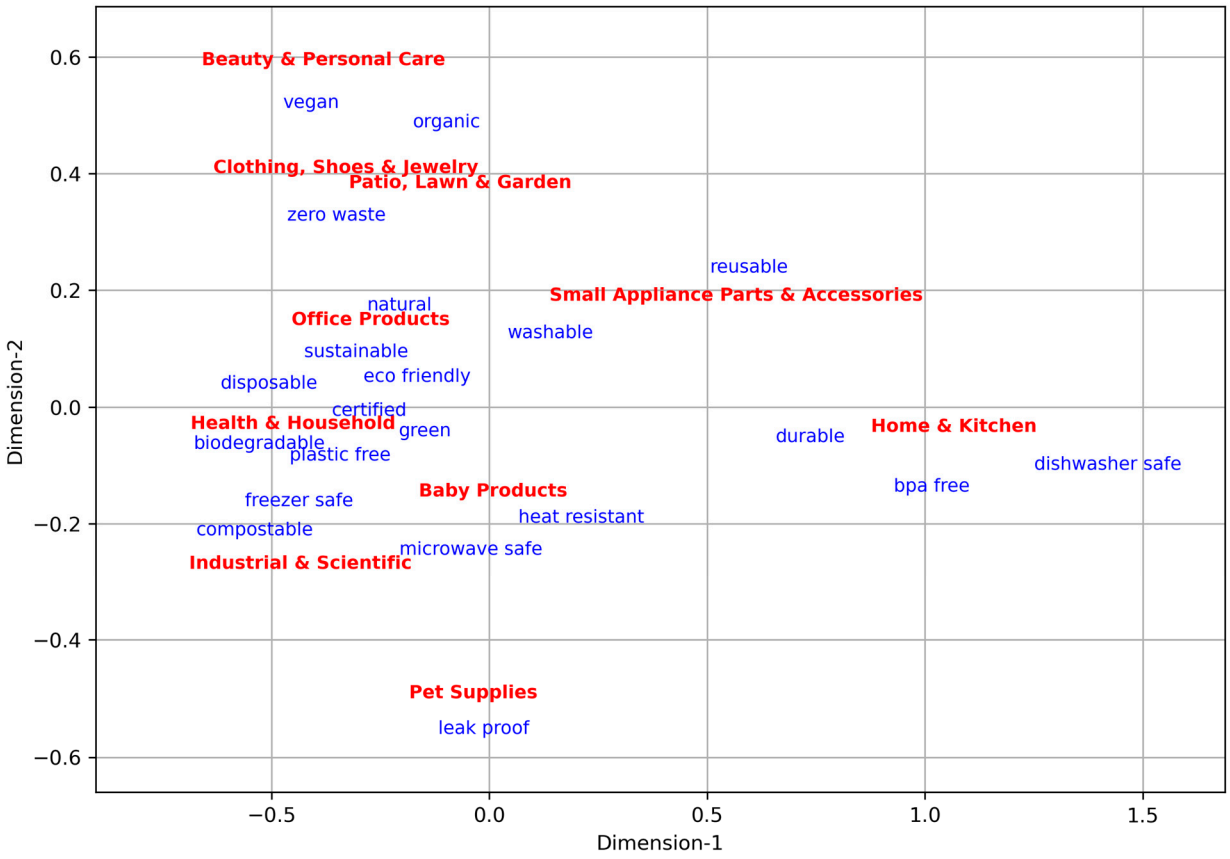


Figure 7. Perceptual map of the relationship between sustainability terms and product categories.

Figure 7 shows a comprehensive visual representation of how different eco-friendly attributes are promoted in conjunction with varied product categories. At a glance, Figure 6 highlights the dispersion of product categories across the map surrounded by several eco-friendly terms that form noticeable clusters of certain sustainability terms near specific product categories. These clusters indicate a distinct set of sustainability attributes that are in fact close to the product category. For example, "Beauty and Personal Care" aligns closely with terms such as "vegan" and "organic", suggesting that consumers might specifically associate these eco-friendly attributes with beauty products. Furthermore, for instance, the proximity of terms such as "durable", "reusable", and "dishwasher safe" to the "Home

and Kitchen" category implies that these are the attributes that consumers predominantly seek or encounter in home-related products.

To complement Figure 7, Figure 8 shows another perceptual map to provide a systematic understanding of the relationship between various sustainability terms and the materials commonly associated with them. Figure 7 shows the perceptual map to illustrate how the material used on the products is often perceived in the context of the eco-friendliness concept. At a glance, Figure 8 shows a clear separation of plant-based materials such as "palm leaf", "bamboo", "wood", and "paper" with materials such as "glass" and "stainless", while the position of "cotton" is far from other plant-based materials, which might indicate that the material has different purposes that can be revealed by surrounding eco-friendly terms.

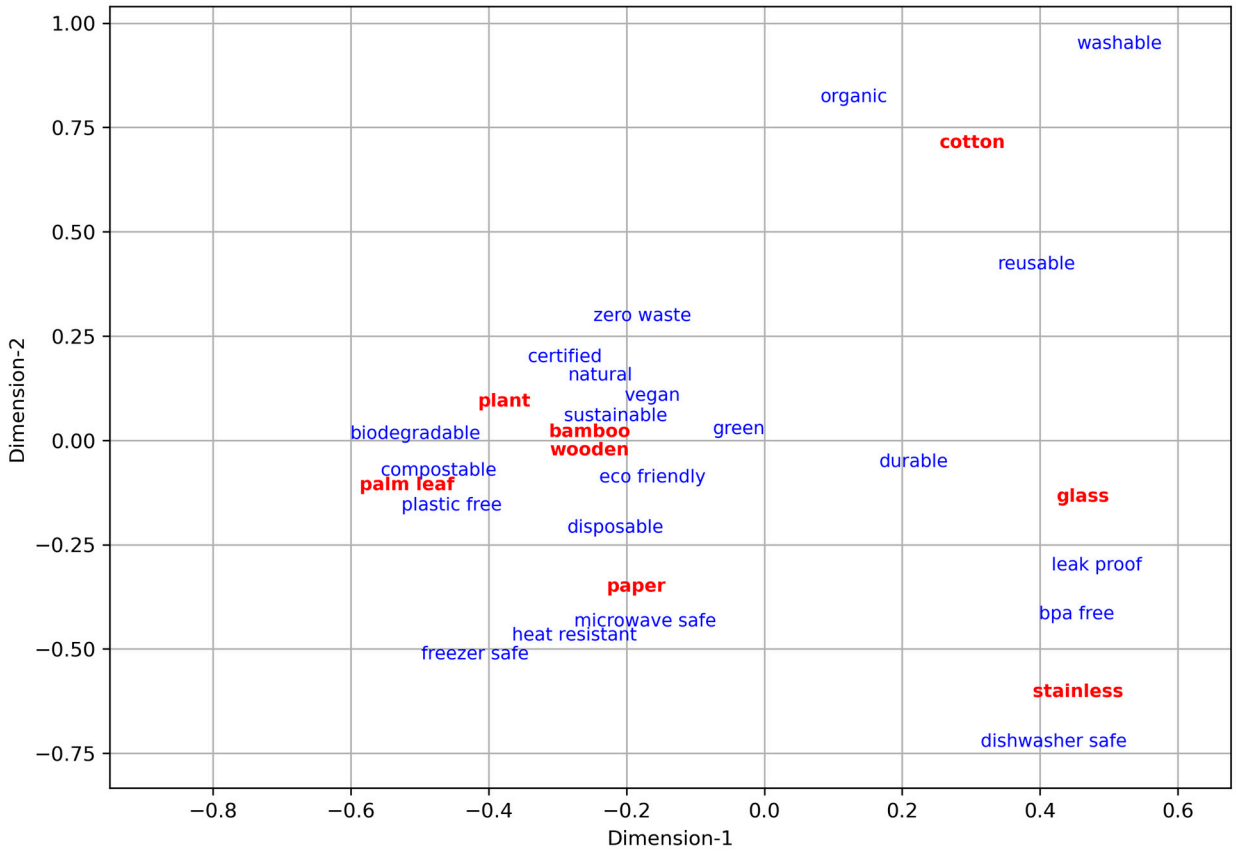


Figure 8. Perceptual map of the relationship between sustainability terms and material applied.

Upon a closer examination of Figure 8, in the top right, the material "cotton" is related to "organic", "reusable", and "washable". This positioning suggests that cotton is frequently perceived as an organic material that is easy to wash and makes it reusable. Meanwhile, the central clustering of terms such as "natural", "vegan", and "sustainable" around materials such as "plant", "bamboo", and "wooden" addresses a common perception of these materials being inherently eco-friendly. Apart from being eco-friendly and disposable, "paper" materials are also closely related to terms such as "heat resistant", "freezer safe", and "microwave safe", which implies that paper products are frequently perceived for their resilience to extreme temperatures. On the other side, the presence of "stainless" alongside "dishwasher safe" and "bpa free" in the lower right section possibly indicates a common perception that stainless steel products are both safe for dishwashing and free from harmful chemicals.

3.2. Customer Sentiment Analysis

To evaluate how sustainability attributes of products on Amazon are received in the market, analyzing user sentiment is becoming essential. Therefore, in this research, we examined the sentiment in user reviews, with a particular focus on comments that reference the eco-friendly attributes discussed in the previous section. Even though consumer reviews can express both positive and negative sentiments, our analysis revealed the dominance of positive sentiment toward eco-friendly products on Amazon. Consequently, this section will concentrate on positive sentiments to further understand specific aspects of user satisfaction. Through detailed tables and perceptual maps, this section aims to highlight the relationship between sustainability attributes and user satisfaction.

Starting the analysis of user sentiments, Figure 9 depicts the spectrum of consumer sentiments corresponding to various eco-friendly key terms identified during the earlier phase of product analysis. These sentiments have been extracted from user comments that specifically mention the associated sustainability attributes. Figure 9 clearly distinguishes between positive and negative mentions of each eco-friendly attribute and, at the same time, shows how each eco-friendly attribute is perceived by consumers.

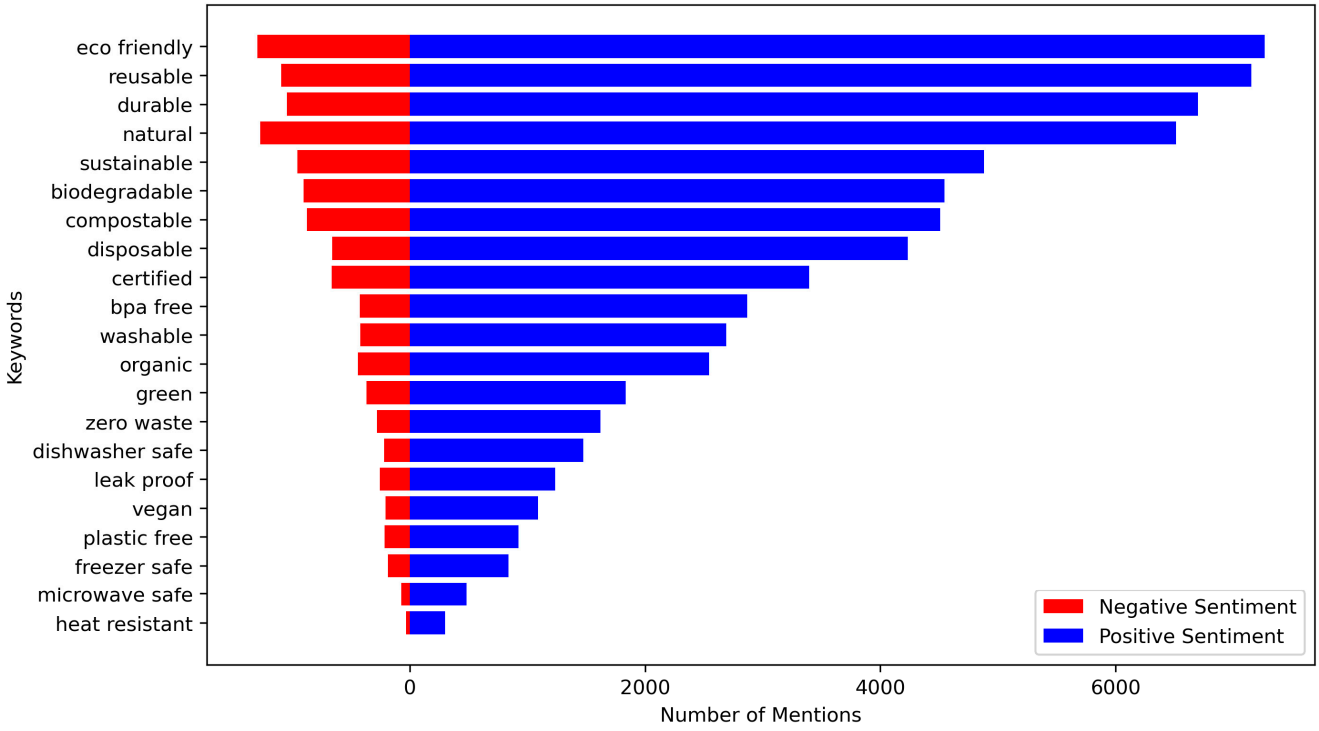


Figure 9. Distribution of positive and negative sentiments for eco-friendly key terms.

As depicted in Figure 8, terms such as "eco-friendly", "reusable", and "durable" have notably high positive mentions, addressing that the associated product with that label commonly gains a good reception among consumers. Meanwhile, terms such as "heat resistant" and "microwave safe" also garnering positivity could be attributed to the functionality that they bring, implying that consumers value both the sustainability and practicality of products. The overwhelming positive sentiment toward these eco-friendly terms suggests that general sustainability claims are well received by the user base and well represented by the product. This might be indicative of a broad acceptance of sustainability as a value in purchasing decisions.

Following the general user sentiment depicted in Figure 9, it is evident that the majority of users express positive sentiments toward eco-friendly products. This overwhelming positive sentiment suggests a general approval and appreciation of these products' attributes and benefits. Hence, to comprehensively understand the underlying aspects of this

widespread positivity, we then categorized those positive sentiments into certain aspects of user satisfaction. By categorizing sentiments into user satisfaction aspects, we can be concerned with the particular attributes of eco-friendly products that resonate most with consumers. For this purpose, Table 2 offers a structured breakdown of these user satisfaction aspects and outlines the key factors driving users' positive reception, represented with several terms that represent different fashions of positive sentiment. These terms are then classified into four types of user satisfaction aspects of eco-friendly products, namely "Product Quality", "Product Usability", "Product Appearance", and "Product Price Money Value". Information in Table 2 provides more insight that the products labeled as eco-friendly are not only environmentally responsible but also align with user expectations in terms of quality, usability, appearance, and value for money.

Table 2. User satisfaction aspects: related sentiment key terms and their frequencies.

Satisfaction Aspect	Related Key Terms	Occurrence Frequency
General Product Quality	impressed	933
	perfect	7690
	good quality	1473
	great product	1423
	works great	828
	strong	3383
	perfectly	4217
	safe	1701
Product Usability	easy	8392
	easy use	1748
	smooth	987
	easy clean	2303
	comfortable	1073
	efficient	231
	quickly	1830
	easily	3359
	handy	675
	fit	1414
Product Appearance	cute	1977
	fine	2424
	beautiful	973
	light	3024
	lovely	388
	nice	6884
	nicely	1037
	cool	701
Product Price Money Value	cheap	1682
	great value	686
	great price	420
	good value	511
	great price	420
	worth	2307

As depicted in Table 2, on the "Product Quality" aspect, the terms "perfect", "good quality", and "great quality" are generic terms used by users to express general satisfaction with product quality and are predominant, with a significant number of occurrences throughout the dataset. Another notable term is "strong", which signifies the product's reliability and robustness. The usability of a product often determines its acceptance by users. On the "Product Usability" aspect, the terms "easy", "easy clean", "comfortable", "handy", etc., on the other hand, address the convenience and practicality of these eco-friendly products in day-to-day usage. Afterward, the aesthetics of a product play a significant role in user satisfaction. The terms under "Product Appearance" emphasize

this, with "nice" and "cute" being frequently mentioned. Such a variety of terms, from "beautiful" to "cool", shows the variation in the aesthetic appeal of eco-friendly products. Lastly, the "Price Money Value" category demonstrates consumers' eagerness for the cost-effectiveness of the products. Terms such as "worth", "cheap", and "great value" further support this, suggesting that eco-friendly products are not only beneficial for the environment but also for the user's pocket. This user satisfaction aspect indicates that users believe that they are receiving good value for their money.

After the examination of the positive sentiments from users and their related satisfaction aspects as depicted in Table 2, we then investigated the connection of these aspects with previously discovered sustainability attributes. For this purpose, we provide a perceptual map, presented in Figure 10, to show the relationship between sustainability attributes and the specific satisfaction aspects that users associate with them. Using that perceptual map, we provide a comprehensive evaluation of how product attributes resonate with user satisfaction dimensions. Apart from the relationship between the satisfaction aspects and the eco-friendly attributes, the map displays the proximity of these attributes to certain aspects, addressing how consumers perceive eco-friendly products in relation to their quality, usability, appearance, and value.

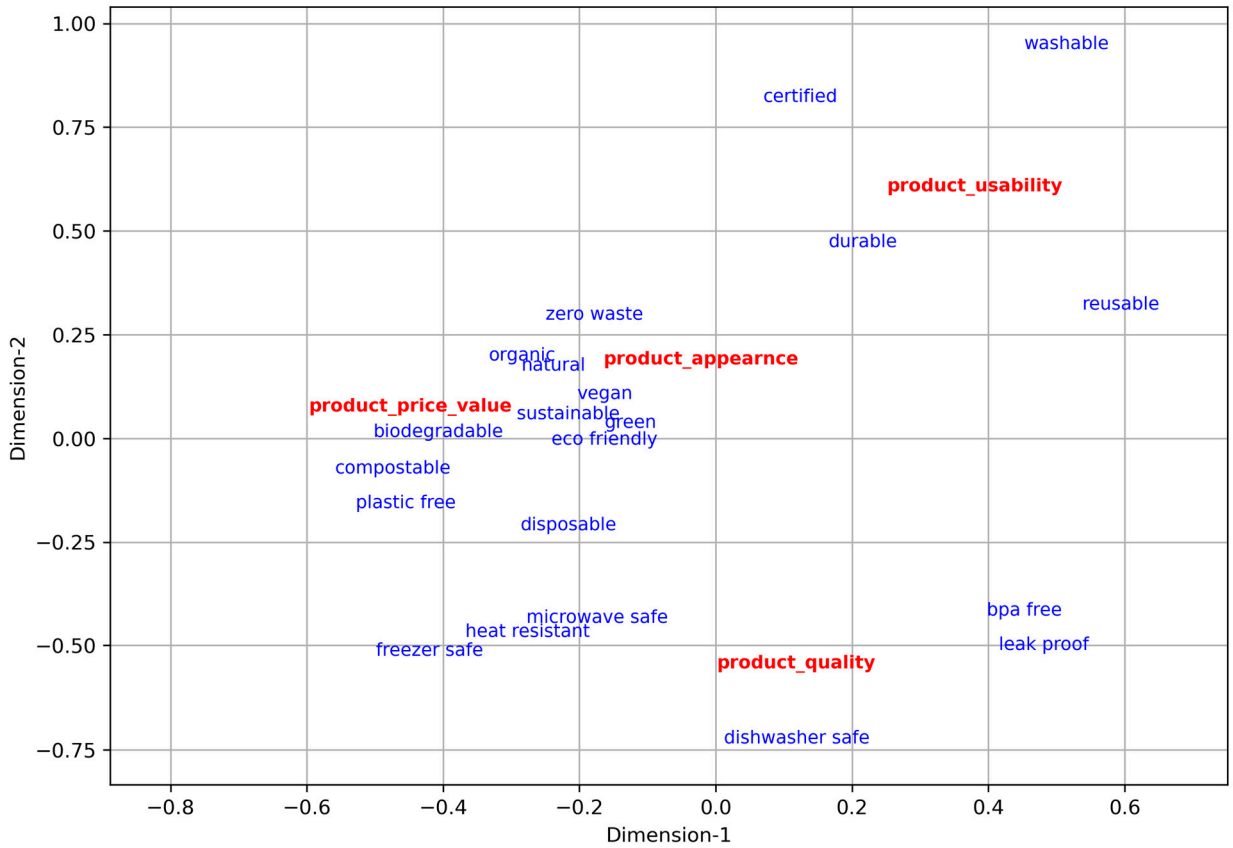


Figure 10. Perceptual map of relationship between sustainability attributes and user satisfaction aspects.

Figure 10 presents how various attributes associated with eco-friendly products correspond to different aspects of user satisfaction. As can be seen in Figure 10, the map is divided into quadrants, each highlighting a distinct association between product characteristics and consumer expectations. A cluster of terms associated with "product usability" occupies the upper right quadrant, featuring descriptors such as "reusable" and "durable". This indicates a strong consumer preference for eco-friendly products that offer practicality and longevity and do not necessitate frequent replacement. In contrast, the upper left quadrant shows a close relationship between the aesthetic aspects of products—denoted by

terms such as "organic" and "sustainable"—and the "product appearance". This suggests that consumers often associate the visual design and branding of eco-friendly products with their natural and environmentally sound credentials.

On the other side of the map, the "product quality" aspect is situated near pragmatic features such as "dishwasher safe" and "leak-proof", located in the lower right quadrant. This positioning underscores the consumer expectation that eco-friendly products should not compromise on functionality or reliability. This finding stresses the importance of high performance as a key driver of satisfaction among eco-friendly product users. Lastly, the perceptual map reveals a segment with terms such as "certified" and "washable", which are somewhat distant from the central clusters. These attributes may be considered secondary to the core qualities that users seek in eco-friendly products. Certification may serve as a formal validation of eco-friendliness, and washability adds a layer of convenience, yet these factors are possibly not as influential in the immediate perception of the product's sustainable value or its day-to-day utility.

4. Discussions

4.1. The Significant Emergence of Positive Feedback and Consumer Satisfaction Aspects

The analysis of user reviews showed the dominance of positive sentiments regarding eco-friendly product attributes, indicating that a large portion of consumers appreciate sustainable products. This is in line with some investigations that stated that the prominence of that positive sentiment reflects the growing inclination toward environmental issues among the general public [36,37]. Upon a more detailed examination of positive sentiments, we identified specific satisfaction aspects, such as product quality, usability, appearance, and value for money. These findings suggest that users evaluate sustainable products not only based on their eco-friendly attributes but also based on how these attributes intersect with other product qualities. Therefore, sustainability should not be considered as a separate or isolated feature from the specification of the product itself. Accordingly, some research suggests that the interconnection of eco-friendly attributes with other product characteristics drives user satisfaction [38,39]. To reveal how users perceive the relationship between sustainability attributes and satisfaction aspects, we then provide a perceptual map created from the correspondence analysis.

The strong positive sentiments discovered in the user reviews address certain trends indicating that a market is increasingly favoring sustainable products. This information is beneficial for the business which needs to take note of this trend. Ignoring the sustainability aspects of certain products discussed in this article might result in missed opportunities and a reduced market share, especially when competitors are catering to this growing demand. Nevertheless, from the revealed user satisfaction aspects and the correlation of those aspects with sustainability attributes, there is also a necessity to give attention to the product quality, usability, appearance, and value as well. As environmental concerns gain increasing consumer attention, businesses that incorporate sustainability into their product designs and marketing strategies while also considering other key satisfaction drivers are likely to have a competitive advantage in the market.

Furthermore, we then performed a follow-up study by conducting further literature reviews to validate our results. Our comprehensive literature review draws upon several research studies that show the significant influence of sustainability attributes on consumer satisfaction across diverse sectors. In the retail industry, several studies highlight the critical impact of an eco-friendly image in enhancing customer satisfaction and trust [40–42]. Those studies reinforce that sustainability practices are crucial for improving customer satisfaction. This aligns with our findings on the positive influence of sustainability on consumer attitudes.

In the hospitality sector, another study examines the effect of ecolabels on service quality in eco-labeled hotels and restaurants [43,44]. It reveals that green practices are recognized as a distinct service quality dimension, contributing to higher guest satisfaction. This finding echoes the importance of sustainability initiatives as a differentiation strategy

in the market. Those studies also support our argument about sustainability attributes' amplifying effect on customer satisfaction.

Eventually, those five studies [40–44] collectively validate our initial findings, demonstrating the significant impact of sustainability initiatives across various industries on customer trust, satisfaction, and loyalty. The universal applicability and strategic importance of integrating sustainability into business practices are thus highlighted, emphasizing its role in enhancing consumer satisfaction and loyalty.

4.2. Practical Implications for Product Design Optimization

This section presents a series of targeted recommendations aimed at designers and stakeholders related to eco-friendly product development. These recommendations, derived from our analytical insights, address critical aspects of product design optimization, including quality, usability, aesthetics, and the use of sustainable materials. Each Section, (4.2.1–4.2.4), delves into specific strategies and considerations. These suggestions are not only based on consumer preferences and perceptions as revealed through our analysis but also reflect a broader commitment to environmental responsibility in product design. By implementing these recommendations, designers and manufacturers can enhance the appeal and sustainability of their products, meeting the evolving demands of the eco-conscious consumer.

4.2.1. Emphasis on Product Quality

Our results section highlights the importance of product quality in user satisfaction. High-quality products often last longer and it is not necessary for them to be replaced as frequently, which leads to waste reduction. This statement is in line with our findings that show that "product quality" occupies a pivotal position in the consumer evaluation of eco-friendly products. The proximity of terms such as "dishwasher safe" and "leak-proof" to the "product quality" as consumer satisfaction aspects address their expectation that eco-friendly products must not compromise on performance. Our results further suggest that, for eco-friendly products to be competitive, they must not only meet the ecological expectations set forth by their 'green' labeling but also align with the acceptable standards that consumers have come to expect from all product categories.

The terms that emerge around "product quality" on the perceptual map are common terms used to reflect certain standards of specified products ("bpa safe", "freezer safe", "heat resistance", etc.). Hence, the direct implication of this insight for designers and manufacturers is the importance of incorporating these standards as a central design principle. This can be achieved through the careful selection of materials and robust construction techniques. Even though consumers are driven by environmental considerations, their satisfaction with eco-friendly products is in line with the functional robustness of these items. Hence, related to product quality, we can suggest that product designers consider using durable materials and that adopting robust construction techniques can ensure longevity. By ensuring that environmental products are not only sustainable but also meet high functional standards, producers can foster greater consumer satisfaction and support the broader adoption of eco-friendly products.

4.2.2. Importance of Usability

Our results show that usability significantly affects user satisfaction as users repeatedly mentioned terms such as "easy", "handy", "safe", and "efficient" when describing their positive experiences. These terms address certain facts that consumers have positive affirmation toward products that simplify their lives and save them time. The evidence from the user reviews shows that there is much feedback that products need to be both sustainable and user-friendly. Users who found products "easy to use" or "smooth" in their operation were more likely to leave positive feedback and have a more positive perception of the product's sustainability features. Hence, as usability emerged as one of the most important factors of user satisfaction, ensuring that a product is not only functional but also

user-friendly can enhance its market reception. This emphasis aligns with the principles of "Design for User Experience" and "Modular Design", which have been introduced and examined in several studies [45–49].

Reviews that were related to product usability, like the ease of assembly or maintenance, were close to terms such as "washable" or "durable" on the CA perceptual map. The terms "washable" and "durable" show the consumer's expectation of usable products. A washable product suggests an eagerness of the consumer for the product to withstand regular use and be easily cleaned without significantly degrading the product's functionality. These terms are contingent on the "durable" term, which is situated in the same space to address the product's longevity. Thus, in the eyes of the consumer, usability is not just about the immediate experience but also about the product's performance in the long run. Additionally, the term "reusable" underscores another aspect of usability. A reusable product not only offers extended utility but also how consumers can find value in products that can be used multiple times for varied purposes.

4.2.3. Balancing Sustainability and Aesthetics

In terms of visual appearance, our results clearly show that how a product looks is important to users. Words like "beautiful" and "lovely" came up a lot, which shows that users care about the visual appeal of a product. Therefore, the sustainability aspects of products need not compromise on aesthetic factors. In our perceptual map, products described as "sustainable" and "eco-friendly" also received compliments for their design. Terms that reflect aesthetic aspects of products, such as "beautiful" and "lovely", were often found in proximity to words that stressed sustainability, such as "vegan", "natural", "eco-friendly", and "organic". These terms suggest that when the product is visually appealing, the consumer often also refers to its eco-friendly attributes. In other words, for many consumers, a product's aesthetics and its green credentials are interlinked.

Other terms close to the visual aspect of the products such as "organic" or "zero-waste" are not merely viewed as functional attributes but also as aesthetic qualities. The perceptual map shows that the modern consumer finds beauty in sustainability. For example, a bag made from organic cotton might not just be appreciated for being sustainable, but also for the natural look and feel of the material. Similarly, a "zero-waste" design might appeal to users not just for its environmental benefits but also for its minimalist and efficient design. This relationship between product appearance and eco-friendly terms suggests a novel preference in the modern consumer's aesthetic preferences. Products that emphasize their natural, green, or organic attributes are not merely considered as responsible choices but also as stylish ones. Therefore, this evidence addresses an opportunity for designers and manufacturers to use eco-friendly materials in innovative ways to make products that users find appealing in terms of both looks and sustainability.

4.2.4. The Use of Compostable Materials

From our results, terms such as "biodegradable" and "compostable" frequently appeared. These terms indicate that people are more aware of waste issues and appreciate products that can naturally degrade over time. When a product is labeled as compostable or biodegradable, it is claimed as harmless for the environment as it would break down. Our results also show a favorable sentiment toward "plastic-free" products, indicating the awareness of the harmful effects of plastic waste on the environment. This finding is in line with several studies that indicate a growing consumer preference for plastic-free products and a heightened awareness of the environmental impact of plastics, reflecting a significant shift toward sustainability in consumer behavior [50,51]. Additionally, in our perceptual map of sustainable materials, terms such as "bamboo", "wooden", and "plant" have close associations with "compostable" and "biodegradable" terms. This association not only highlights the preferred materials but also emphasizes the consumer concern for environmentally friendly options.

Offering compostable or plastic-free options can be both an environmental and strategic choice in design. Nevertheless, for a product design to be genuinely sustainable, it is crucial to incorporate consideration from environmental or sustainability experts. Their expertise can ensure that sustainability claims are not just surface-level marketing gimmicks but have a genuine positive impact. A great example is Adidas's collaboration with Parley for the Oceans (https://parley.tv/initiatives/adidasxparley, accessed on 2 October 2023). By partnering with experts, Adidas developed shoes made from up-cycled ocean plastic, turning a pressing environmental problem into a sustainable solution.

5. Conclusions

In our study, the terms related to "eco-friendly" or "sustainable" labeled on any kind of product are evidently perceived positively among consumer, indicating their acceptance of the product value that is designed with environmental fashion. Our results showed that more than 90% of sentiments toward sustainable products are positive. Conversely, while negative sentiments are comparatively lower, they are not completely absent. Therefore, the associated review of these sentiments might point to areas where there might be misconceptions or room for improvement in product communication or performance. Eventually, we can conclude that product designs that prioritize sustainability are catering to a growing group of environmentally conscious consumers. Nevertheless, in our discussion, we emphasize that the fundamental basis of any product design should focus on its end-users. While sustainability is a driving factor toward product acceptance, especially for consumers who have an awareness of environmental issues, the final product should align with their needs and experiences. A sustainable product that is difficult to use or fails to meet the consumer's requirements can lead to dissatisfaction and reduced adoption rates. Therefore, the design process considers the evolving user feedback and market trends. Revisiting design decisions based on real-world user experiences ensures that products stay relevant and continuously improve.

This research, while yielding significant insights, encounters certain limitations that necessitate future exploration. Our study's focus on Amazon's "Climate Pledge Friendly"-labeled products, though providing a valuable perspective on consumer perceptions within a major e-commerce platform, inherently restricts the breadth of our inquiry to a singular marketplace. This limitation is further compounded by potential biases inherent in consumer reviews, which may not always reflect the broader consumer population's perspectives or experiences. Moreover, the study's reliance on data from one platform raises questions about the generalizability of our findings to a wider audience. Additionally, the current research design predominantly captures a static view of consumer attitudes, lacking a longitudinal dimension to examine how these attitudes and behaviors evolve in response to changing market trends and growing consumer awareness over time. These constraints, inherent in our study's scope, underscore the need for broader, more diverse research approaches in the future.

To address these limitations, future research should expand beyond the confines of a single e-commerce platform and incorporate a variety of platforms, such as eBay, Etsy, and Alibaba. This expansion would help to mitigate the biases associated with consumer reviews from a singular source and enhance the generalizability of the findings. Further, future studies are encouraged to delve into the dynamic relationship between sustainability attributes and consumer satisfaction, examining diverse sustainability practices and their distinct impacts on customer perceptions over time. Such longitudinal studies would offer a richer, more comprehensive understanding of evolving consumer behaviors and attitudes in the context of sustainability, providing a holistic view of these dynamics across various market settings and consumer demographics.

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N.L.F.; visualization, M.R.M. and N.L.F.; supervision, N.L.F.; project administration, M.S.; funding acquisition, N.L.F. All authors have read and agreed to the published version of the manuscript.

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