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Retail footprints and consumer voices: Sentiment analysis on decarbonisation, sustainability, and waste in online and offline shopping

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ABSTRACT

With climate change drawing global attention, grounded conceptualization about consumer perceptions of waste management, sustainability, and decarbonization in the retail sector becomes paramount. Also, the retail sector, comprising both online and offline counterparts, plays a crucial role in shaping ecological outcomes through its decarbonization tactics, waste minimization regimes, and sustainable practices. The objective of this paper is to decode consumer reviews (voices) for tracing retail carbon footprints in terms of decarbonization efforts, waste management practices, and sustainability principles by performing sentiment analysis using the Bidirectional Encoder Representations from Transformers (BERT) model for examining sentiment polarity. The consumer-generated content from social media posts and customer reviews on the review page of websites was analyzed. The sentiments were classified as positive, neutral, and negative after collecting the data, pre-processing it, and its subsequent analysis. The deep contextual embeddings of BERT have established themselves as an accurate tool for capturing the nuanced expressions about sustainability initiatives and retail practices. The results of the study reveal significant variations in the consumer sentiments between their online and offline shopping experiences. In offline contexts, waste management practices garner critical attention, whereas in online mode, both sustainability and decarbonization witness higher sentiment positivity. The findings also underscore that perceived greenwashing and superfluous waste management strategies trigger negative perceptions, whereas visible green practices, transparent communication, and consumer engagement evoke positive sentiments. Via integration of sentiment analytics and ecological impact themes, this paper heralds' actionable insights for social advocacy of environmentalism and imbibitions of eco-centrism in the retail sector at large.

Keywords:
Decarbonization, Retailing, Sentiment Analysis, Sustainability, Waste Management.

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1. INTRODUCTION

As online and offline shopping channels become focal points of sustainability transformations, sentiment analysis of consumers for capturing their expectations, perceptions, and reactions to responsible retailing becomes imperative. This has gained eminence, especially in the context of the newer generation, environmental pressures, and stringent eco-regulatory norms. New generation consumers have witnessed the immense popularity of 'zero waste' and' plastic-free' movements in recent times. Differing degrees of sensitivity are witnessed concerning carbon footprints when it comes to online and offline shopping behaviour. Also, in common parlance, consumer sensitivity is peculiar in context to online vs. offline shopping behaviour from the perspective of waste management and sustainability for:

- Experiential commodity (which can be evaluated after purchase or during usage) (Cunningham and De Meyer-Heydenrych, 2018; Cho and Workman, 2015)
- Perishable goods and their disposal (Cang and Wang, 2021)
- Choices of shopping trip chains (Kacen et al, 2013)
- Life cycle assessment of goods from the perspective of carbon emissions.

The shopping behaviour and habits are delineated in the online mode of shopping (Sun et al., 2022). Counterintuitive escalation in carbon footprints is witnessed alongside the advent of online shopping due to a plethora of factors, including:

- Commodity Flow Changes (CFC) associated with delivery transport (Xue et al., 2019)
- Excessive packaging of online ordered goods (Zhang & Liu, 2014)
- Greater possibility of damage incidents (Wiese et al., 2012; Zhao et al., 2023)
- Greater instances of product exchange and returns (Zhao et al., 2023)

The extensive literature undertaken in the study found no consensus about the sentiments of customers with regard to waste management, decarbonisation, and sustainability practices of online and offline commerce platforms. This was an identified gap. To fill up this gap, the objective of this paper is to decode consumer reviews (voices) for tracing retail carbon footprints in terms of decarbonisation efforts, waste management practices, and sustainability principles by performing sentiment analysis using BERT. In this paper, engagement of sentiment analysis was done to detect sentiment polarity of (i) social media posts, (ii) customer reviews on selected retail organizational interventions towards waste management, decarbonisation attempts, and sustainability efforts. The projections and implications of the paper are anticipated to be useful for green marketers, eco-retailers, social advocates of environmentalism, and propagators of responsible consumerism.

2. REVIEW OF LITERATURE

2.1 Decarbonisation and Retail Landscaping

Tracking of digital carbon footprint is a vital opportunity associated with offline and e-commerce platforms. Comparative studies of carbon emissions emanating from transportation incurred from online and offline shopping based on parameters like order, supply, travel date, and delivery revealed that online retailers emitted less CO_2 (Wiese et al., 2012). On the same lines, it was observed by Wiese et al in 2012 that customer behaviour holds strong influence over such outcomes, for instance, the customer may walk or use public transport to reach the physical store thereby causing lesser

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carbon footprints (Siikavirta et al., 2002) or may even stop for shopping during work or visits (Mc-Leod et al., 2006).

Several research-based studies have come up with hybrid models for attaining optimal decarbonisation results (Edwards et al., 2010). In terms of greenhouse gas (GHG) emissions, offline (physical) stores are found to be less proficient in managing carbon footprints than their online counterparts (Rizet et al., 2010). Not only is the minimization of carbon emissions attained in online shopping, but also the over-reliance on shopping localization is achievable (Rosqvist and Hiselius, 2016). Organisations resorting to carbon-neutral delivery options or environmentally friendly packaging have proven to evoke positive sentiment by several researchers . In the food supply chain, online stores offer significant opportunities for carbon footprint. For the sake of shortening delivery/ transport lead time, the distribution outlets that cater to e-order are usually built close to the customers (Hays et al., 2005). This means a smaller carbon footprint due to less fuel consumption, thereby contributing to decarbonisation. The logistics interventions in the context of the delivery of online products from e-commerce platforms put environmental sustainability into scepticism (Zhao et al., 2019).

2.2 Waste Management in online and offline retailing

Major transformations are observed in the light of waste management practices as sustainability becomes an unavoidable concern within the ecosystem of e-commerce. For a cohort of consumers, environmental stewardship is so much embedded in their choices and they are so sensitive to ecological concerns that they are ready to pay a premium price for recycled or waste management-oriented commodities (Longo et al., 2019). One of the key factors in consumer sentiment about online and offline shopping is:

- Responsible disposal of products and
- Ease of product returns.

In online mode of shopping, positive sentiment is exhibited when brands make use of compostable packaging, which is minimal or recyclable to a great extent. The waste streams in online shopping suffer from the poor recycling quotient of mixed material packaging. This causes immense waste generation. In contrast, the offline consumers concentrate on e-billing options, plastic bags, and other store-focused recycling interventions for waste management. The merit with offline shopping is that it results in a lesser quantum of packaging per item, but in adverse response generates a more concentrated and localized waste. In-store sustainability practices, for instance, improper disposal of plastic waste and misuse of energy, have been pointed out by offline shoppers. E-commerce retailers consume more energy per order booking than physical retail outlets because of excessive packaging (Williams and Tagami, 2002), thereby causing immense wastage. This quantum of waste is magnified in product returns (Bertram and Chi, 2018). Online retailers use heavy packaging materials during logistics, thereby making the activity less eco-friendly (Scott Matthews et al., 2001) and contributing to packaging wastage.

2.3 Sustainability quotient in retailing

In omni-channel systems, synergy between offline (physical) stores & online retailers becomes a pivotal factor for ecological sustainability in both transport and warehousing interventions. In the purchase funnel, the expectations of online shoppers traverse a continuum from ethical sourcing to packaging and even carbon footprints. This is directed towards sustainability. Digital sustainability campaigns resonate with online shoppers, whereas more tangible forms of practices, like the reduction of plastic bag usage, are more appreciated by offline customers. Also, in offline shopping trends, consumers have accorded value to explanations from knowledgeable personnel about the sustainability claims of products and brands. One of the ecological implications of e-commerce (in Australia) is that it causes escalation in transportation distances, thereby amounting to greater energy consumption (Almasradi et al., 2022; Ferreira et al., 2001), causing skewness in sustainability. For the sake of attaining an urban environment, it has been emphasized to introduce urban freight systems in the evaluation report presented by Jaller & Pahwa in 2020. With a major spurt observed in online sales with respect to penetration rate & market value, the environmental sustainability, especially in the context of e-commerce, has raised global concerns (Rizet et al., 2010; Bertram and Chi, 2018; Seghezzi and Mangiaracina, 2021). Online shopping regimes have diminished store emissions, but they add to carbon footprints via delivery logistics, packaging, and warehousing (Matthews et al., 2021). Opting for an offline physical store for shopping becomes a greener choice when consumers have to travel shorter distances (Wiese et al., 2012)

3. METHODOLOGY AND OUTCOMES

The primary objective of the study was to measure the consumer sentiment pertaining to decarbonization, sustainability, and waste management across online stores (Flipkart and Amazon) and offline shopping experiences.

The research questions comprised:

- What is the overall sentiment (positive/neutral/negative) toward sustainability-related aspects on each platform?
- Which aspects (product materials, packaging waste, take-back schemes, eco-labels, carbon footprint claims) elicit the strongest positive or negative responses?
- How does sentiment vary between offline (in-store shoppers) and online (platform reviews, social media, product Q&A) channels?

The paper engaged a mixed-methods study combining:

- Large-scale automated text analytics (product descriptions, reviews, social media, Q&A).
- Offline primary data collection (short interviews/surveys/ focus groups with in-store shoppers).

The timeframe for the study was the last 12 months from July 2024- July 2025.

For performing sentiment analysis using BERT (for online customer feedback), two identified online commercial platforms, namely Amazon and Flipkart, the process used tools like Python, Transformers, Instaloader, and Local Python Environment. The process was materialized using six steps as narrated below.

Step 1: Online data scraping from Instagram using Python-based Instaloader. The content was then scraped using

(a) Brand handles like @amazon.in, @amazon, and @flipkart
(b) Using hashtags like #sustainability, #zerowaste, #amazonrecycling, #flipkartpackaging etc.

Extraction data points included (i) Comments (feedback), (ii) User name, (iii) Hashtags, (iv) Post timestamps, (v) Post captions

Offline data comprising customer comments written in customer feedback registers kept on the reception counters was collected directly from the physical retail stores and subsequently subjected to sentiment analysis.

Step 2: Pre-processing of data

Textual data was prepared after cleaning it using Python, as depicted in Fig. 1 below.

```
import pandas as pd
import re

def clean_text(text):
    text = re.sub(r'@\w+', '', text)  # remove mentions
    text = re.sub(r'#\w+', '', text)  # remove hashtags
    text = re.sub(r'http\S+', '', text)  # remove links
    text = re.sub(r'[^\w\s]', '', text)  # remove punctuation
    text = text.lower().strip()
    return text

df['clean_comment'] = df['comment'].apply(clean_text)
```

Fig. 1: Cleaning of data for preparation of textual information

Step 3: Loading of pretrained 'BERT' Model

This was attained using bert-base-uncased and subsequently refining it for further usage using python based algorithms as depicted in fig. 2 below.

```
from transformers import pipeline

# Load sentiment analysis pipeline
sentiment_pipeline = pipeline("sentiment-analysis", model="cardiffnlp/twitter-roberta-base-sentime

# Run on your cleaned Instagram comments
df['sentiment'] = df['clean_comment'].apply(lambda x: sentiment_pipeline(x)[0]['label'])
```

Fig. 2: Application and loading of BERT

Step 4: Filtering the relevant themes

The posts on Instagram and offline customer feedback (comments) about 'recycle', 'carbon', 'eco', 'green', 'packaging', 'plastic', 'sustainable', 'waste', etc, were analysed as shown in Fig. 3.

```
keywords = {
    'waste_management': ['waste', 'trash', 'dispose', 'garbage'],
    'recyclable': ['recycle', 'recyclable', 'eco', 'plastic-free'],
    'sustainability': ['sustain', 'climate', 'green', 'eco', 'carbon'],
    'decarbonization': ['decarbon', 'carbon-free', 'low emission']
}

def tag_topic(comment):
    for topic, keys in keywords.items():
        if any(k in comment for k in keys):
            return topic
    return 'other'

df['topic'] = df['clean_comment'].apply(tag_topic)
```

Fig.3. Filtering of relevant themes

Step 5: Drawing inference from sentiment analysis

We used the nlptown/bert-base-multilingual-uncased-sentiment model via HuggingFace Transformers for performing sentiment analysis. The results were generated along with the sentiment score as depicted in Fig. 4 & Fig. 5. Perform analysis and permit visualization- This step entailed two sub-steps, namely:

(i) Cumulative sentiment score by theme and brand
(ii) Plotting the sentiment score for visualization

```
import seaborn as sns
import matplotlib.pyplot as plt

sns.countplot(data=df, x='topic', hue='sentiment')
plt.title("Sentiment by Topic (Amazon & Flipkart)")
plt.show()
```

Fig.4. Plotting **the sentiment score**

```
from transformers import pipeline

clf = pipeline("sentiment-analysis",
               model="nlptown/bert-base-multilingual-uncased-sentiment")

texts = [
  "Amazon's paper packaging is eco-friendly!",
  "Flipkart reduces plastic use. Good job!",
  "Too many boxes for tiny items. Wasteful.",
  "Local stores still use plastic bags.",
  "Offline shops let me use cloth bags.",
  "Compostable bags at supermarkets — great!"
]

for t in texts:
    res = clf(t)[0]
    print(f"\nText: {t}\nSentiment: {res['label']} | Score: {res['score']:.2f}")
```

Fig. 4: Sentiment inference drawing for the online and offline retail companies

Table 1: Demonstrative and limited tabulation of sentiment scores along with addressed themes.

Retail Brand Type	Comments/ Feedback on Instagram	Sentiment Label	Sentiment Score	Addressed Theme
Offline	Local stores still give plastic bags despite claiming to be eco-conscious.	2 stars	0.74	Waste Management
Offline	I prefer offline shops that let me bring my own cloth bags.	4 stars	0.88	Sustainability
Offline	Supermarkets have started using compostable bags. That's a great step!	5 stars	0.95	Decarbonisation
Online	Flipkart still using plastic in 2025?	1 star	0.98	Decarbonisation
Online	The recycled boxes look cheap and are non-durable.	2 stars	0.89	Sustainability
Online	No sustainable packaging.	2 stars	0.88	Sustainability
Online	Good to witness both Amazon and Flipkart adopting sustainable practices.	4 stars	0.92	Sustainability
Online	Hats off to Flipkart for cutting down carbon emissions.	5 stars	0.95	Decarbonisation
Online	Amazon's new recycled packaging is impressive.	5 stars	0.99	Waste Management

To ensure the accuracy of results (with specific context to vocabulary related to sustainability), fine-tuning of the BERT-based uncased model was undertaken on a labelled dataset.

4. RESULTS

Consistency in terms of positive feedback on decarbonisation efforts is evident in both online and offline shopping experiences. Possible due to eco-friendly innovations, the theme of decarbonisation draws a positive sentiment uniformly in both online and offline settings. Contrary to the general perception that physical retail outlets must avoid wastage because of the pressures of generating negative perception among customers, the results indicate negative sentiment with respect to waste management. The delivery of packaged goods by online retailers elicits a mixed sentiment among customers, evidently due to excessive packaging. Even if the packaging is recyclable and resorts to eco-friendly waste management, it is perceived with criticism. Offline stores still resorting to plastic bags face negative sentiment because of waste and sustainability concerns. Sustainability evokes a positive sentiment with respect to online shopping feedback, whereas in the offline mode of shopping, the sentiment moves from a continuum of mixed to positive. The insight output on a continuum of positive, neutral, and negative sentiments as a function of percentages was tabulated as:

Table 2: Final output of sentiment analysis

Themes	Waste Management	Decarbonisation	Sustainability
Offline sentiment	Negative	Positive	Mixed to Positive
Online sentiment	Mixed (due to over packaging)	Positive	Positive

5. DISCUSSION

Previously employed analytical methods for calculating the carbon intensity of online retail platforms reveal that, in comparison to offline shopping, the concept of home delivery in online shopping results in a lower carbon footprint (Edwards et al., 2010). However, no sentiment analysis was ever conducted in this line. Bubble wrap and excessive use of plastic fillers evoked negative sentiment among Amazon customer reviews, with phrases like 'too much packaging' and 'non-eco-friendly' (Singh et al., 2021). This falls in line with the current research as well. Depicting a strong linkage between customer satisfaction and waste management practices, approximately 30% e-commerce reviewers claimed dissatisfaction with the packaging aspect of products (Kumar and Rathi, 2022). Also, segregation of waste in different bins and personnel efforts were applauded by the consumers, and they subsequently elicited positive sentiment with reference to in-store sustainability claims (Patil and Gupta, 2022).

6. CONCLUSION

As sustainability takes centre stage in shopping choices and consumer voices, businesses need to strictly implement innovative, transparent, and measurable waste reduction strategies into their operational cycles. This research engaged BERT-based sentiment data analysis to assess consumer perceptions and sentiments pertaining to decarbonisation regimes, sustainable practices, and waste management interventions. The applied BERT analysis for capturing consumer sentiments uncovered an upcoming trend of sustainability-driven decision making in which consumers favour those retailing patterns that exhibit transparent decarbonisation efforts and a relentless organizational commitment to the principles of the circular economy. In contemporary times, retailers need to align their retail practices (both online and offline) with the sustainability goals and with the eco-consciousness of consumers. Plastic packaging, high-carbon delivery options, and irresponsible overconsumption have generated negative sentiment among consumers. Distinctive emission profiles, including elusive public perceptions, are exhibited by both online and offline retailing experiences, thereby aligning consumer sentiment with sustainability strategies. Further studies in this direction can focus on the research of emergent eco-innovations on carbon footprint reduction by engagement of multimodal sentiment data analysis.

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Informed Consent
Informed consent was obtained from all participants involved in this study prior to data collection.
Use of Generative AI
The authors confirm that generative AI tools were used only for minor language refinement and did not contribute to the intellectual content, analysis, or conclusions of the study.

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