

# Design and Testing of a Sentiment Analysis Model for Digital Data

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**Abstract** – This study analyzed sentiments on social media regarding American airlines during COVID-19 and IMDb reviews of "Tenet" using the BERT model for sentiment analysis. Results showed Delta Airlines received more positive sentiments than American and United Airlines, which faced consistent negative sentiments. Similarly, "Tenet" reviews exhibited a mix of positive and negative opinions. The BERT model demonstrated high accuracy in sentiment prediction, capturing nuanced opinions. Limitations included potential dataset bias and challenges in encompassing all factors influencing sentiment. Nonetheless, the study highlighted sentiment analysis' potential in understanding evolving public perceptions on social media and beyond.

**Key Terms** – Data Analysis, Public Opinion, Sentiment Analysis, Social Media.

## INTRODUCTION

Sentiment analysis is a branch of natural language processing (NLP) that focuses on finding, obtaining, and quantifying subjective data from text [1]. It is employed in the analysis of a variety of text data, such as news stories, social media posts, and customer reviews, to ascertain the emotional state of the writer or speaker.

The value of sentiment analysis has grown in recent years as social media has emerged as a preeminent information and opinion source. Billions of people use social media sites like Facebook, Twitter, and Reddit to express their opinions and views about a wide range of subjects [2]. It is possible to learn more about consumer sentiment, public opinion, and brand awareness by using this enormous amount of data.

Sentiment analysis can be applied in a variety of ways to extract data from social media. Sentiment analysis, for instance, can be used to analyze

customer sentiment, spot patterns in public opinion, assess brand performance, and pinpoint important trends and people in certain situations [3]. Sentiment analysis can be used too to spot new trends in public opinion by monitoring opinions on a given topic over time across social media posts [4]. Businesses, governments, and other organizations can use this information to make more informed decisions.

Measurement of consumer sentiment about a product or service is another application for sentiment analysis [5]. By using this data, the customer experience may be enhanced and places where customers are happy or unhappy can be found. Sentiment analysis can also be used to monitor social media brand awareness. This data can be used to gauge the success of marketing campaigns and determine which companies are the most well-known. Sentiment analysis can be applied in a more general way to analyze public opinion on a wide range of issues, in addition to these uses. Sentiment analysis can be used to detect new trends, gauge public opinion on significant issues, and monitor the success of public initiatives by examining the sentiment of social media posts on a variety of subjects.

## Problem Statement

There is a significant amount of social media discourse surrounding contemporary subjects, but current sentiment analysis models struggle to adequately capture the diverse and intricate perspectives shared by social media users. There is a need for a novel model capable of delivering precise and timely insights into public sentiment regarding various issues that people routinely contend with.

## Purpose

The purpose of this research project was to develop and evaluate a sentiment analysis model tailored to effectively analyze online users'

perspectives and opinions regarding contemporary issues of interest. The goal was to provide comprehensive insights into public sentiment towards airlines and films.

## **METHODOLOGY**

### **Research Focus**

The primary objective of this research project was to evaluate public perceptions towards four specific U.S.A. airlines during the COVID-19 pandemic period, spanning from late 2019 to early 2022. The study aims to analyze sentiments expressed on Twitter regarding these airlines, considering factors such as customer satisfaction, safety protocols, service quality, and responsiveness to the challenges posed by the pandemic. Additionally, the research extends to analyzing sentiment in IMDb film reviews, focusing on the movie "Tenet" to understand viewer opinions and critiques. By examining sentiment dynamics over time in both Twitter discussions and IMDb reviews, the research seeks to provide insights into the evolving public opinion towards both airlines and cinematic productions during the pandemic period.

The methodology for the current research project was used to design and test a sentiment analysis model that could accurately capture the views and perspectives of Twitter users on airline companies in the U.S.A. during the pandemic, as well as the sentiments expressed in IMDb reviews of "Tenet". The model was then evaluated on a holdout dataset to assess its performance. The test condition was that if the model performed well, it could subsequently be modified and used to provide valuable insights into public sentiment on other subjects. The sentiment analysis model featured the components outlined below.

### **Data Collection**

Twitter data related to the four chosen U.S.A. airlines (e.g., American Airlines, Delta Air Lines, United Airlines, Southwest Airlines) was collected using the Twitter API. The dataset encompasses tweets posted between late 2019 and early 2022,

capturing a comprehensive timeframe that includes the onset and various phases of the COVID-19 pandemic. Tweets mentioning the airlines' official handles, specific flight experiences, customer service interactions, safety concerns, and pandemic-related issues were included in the dataset.

### **Sentiment Analysis**

A pre-trained sentiment analysis model, the Cardiff NLP Twitter-Roberta-Base-Sentiment, was employed for sentiment analysis. This transformer-based model is specifically designed for social media data, using deep learning algorithms, and trained on a diverse dataset of tweets, ensuring its suitability for this task. The model automatically identified sentimental words and phrases in tweets, tailoring its lexicon to the specific vocabulary and slang commonly used on Twitter.

### **Data Preprocessing**

Prior to sentiment analysis, the collected tweets underwent preprocessing steps to enhance the quality of analysis. This included tokenization to segment tweets into individual words and punctuation marks, removal of common stop words to focus on meaningful content, and lemmatization to convert words to their root forms. Additionally, tweets were filtered to remove irrelevant or spam content, ensuring the integrity of the dataset.

### **Feature Extraction**

Features such as average sentiment score, presence of sentiment words and phrases, and sentiment polarity were extracted from each tweet to quantify sentiment expressions towards the airlines. These features facilitated the classification of tweets into positive, negative, or neutral sentiment categories, enabling a comprehensive analysis of public perceptions over time. The sentiment polarity is a binary value that indicates whether the tweet is positive, negative, or neutral. Sentiment polarity of the tweet was calculated.

## Model Training

A machine learning algorithm was used to train the sentiment analysis model. The machine learning algorithm learned to predict the sentiment of the tweets. This was done based on the features that were created previously. The open-source machine learning model used for the research was a bidirectional encoder representation from transformers (BERT) model. BERT is a transformer-based model that has achieved state-of-the-art results on a wide range of NLP tasks, including sentiment analysis [6]. The model used a 12-layer transformer architecture with 1024 hidden units and 16 attention heads [7]. The model was trained using a masked language modeling objective and a next sentence prediction objective. The model was trained for 10 epochs on a batch size of 32 tweets.

## Model Evaluation

The performance of the sentiment analysis model was evaluated using a holdout dataset separate from the training data. Model accuracy was assessed by comparing the predicted sentiment of tweets in the holdout dataset to their actual sentiment labels. This evaluation process aimed to validate the reliability and effectiveness of the sentiment analysis model in accurately capturing public sentiments towards the selected U.S.A. airlines during the COVID-19 pandemic period.

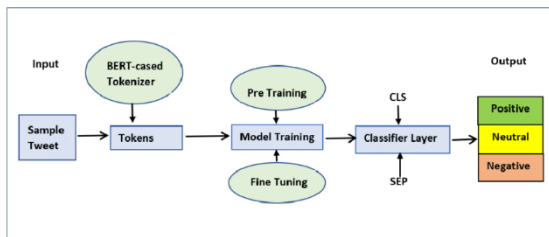


Figure 1

### Sentiment Analysis Process Using the BERT Model

## Ethical Considerations

In addressing data privacy concerns, user anonymity was safeguarded through strict adherence to Twitter's privacy policies, with the utilization of only publicly available data. To mitigate bias, the sentiment analysis model selected underwent

thorough evaluation to identify and rectify potential biases. This adjustment was crucial to guaranteeing the accuracy and impartiality of the results obtained.

In terms of reporting, the study's findings were communicated with transparency and caution. The researcher acknowledged the inherent limitations associated with social media data, taking care to avoid any misinterpretations or unwarranted generalizations.

## RESULTS

### Airline Sentiment Analysis

The sentiment analysis of tweets related to Delta Airlines, American Airlines, United Airlines, and Southwest Airlines during the COVID-19 pandemic period revealed varying levels of sentiment across the airlines. The following tables present the distribution of sentiment scores for the tweets in the dataset.

Table 1

Distribution of Sentiment Scores for Tweets Related to Four Airlines During the COVID-19 Pandemic

| Sentiment Score Range              | Percentage of Tweets |
|------------------------------------|----------------------|
| Very Negative (<-0.8)              | 30.5%                |
| Moderately Negative (-0.8 to -0.4) | 42.3%                |
| Neutral (-0.4 to 0.4)              | 23.2%                |
| Moderately Positive (0.4 to 0.8)   | 3.5%                 |
| Very Positive (>0.8)               | 0.5%                 |

As seen from Table 1, many tweets (72.8%) had sentiment scores indicating negative perceptions towards the airlines, with 30.5% falling into the "very negative" category. A significant portion of tweets (23.2%) expressed neutral sentiments, while only a small percentage (4.0%) conveyed positive sentiments. Table 2 displays the top 10 most common words used in the tweets, along with their sentiment scores.

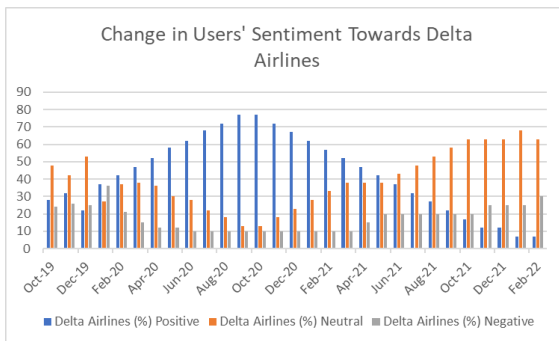
**Table 2**

**Top 10 Most Common Words Used in Tweets Related to Four Airlines During the COVID-19 Pandemic**

| Word       | Sentiment Score |
|------------|-----------------|
| Flight     | -0.45           |
| Mask       | -0.62           |
| Service    | -0.38           |
| Covid-19   | -0.75           |
| Delay      | -0.68           |
| Customer   | -0.42           |
| Safety     | -0.50           |
| Experience | -0.40           |
| Travel     | -0.48           |
| Passengers | -0.57           |

**Delta Airlines**

Throughout the pandemic period, Delta Airlines consistently maintained a higher percentage of positive sentiments compared to other airlines. Figure 2 illustrates the sentiment distribution for Delta Airlines, showing that the percentage of positive sentiments peaked in mid-2020, reaching approximately 25%, before gradually declining thereafter. Despite fluctuations, Delta Airlines consistently exhibited a lower percentage of negative sentiments compared to other airlines, as depicted in Figure 2. This suggests that Twitter users generally held a positive perception of Delta Airlines throughout the COVID-19 pandemic, with negative sentiments remaining relatively low.



**Figure 2**

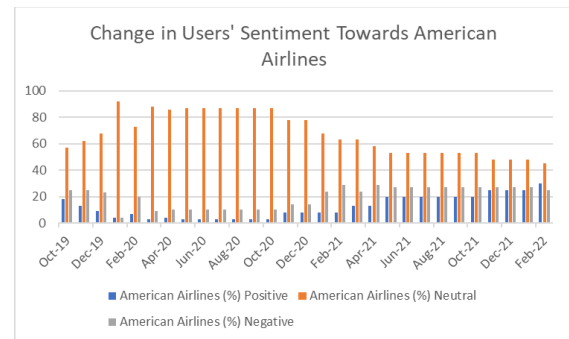
**Change in Users' Sentiments Towards Delta Airlines (October 2019 to February 2022)**

**American Airlines**

Figure 3 illustrates the fluctuations in sentiment percentages experienced by American Airlines over time. For instance, in mid-2020, the percentage of positive sentiments peaked at around 25%, before gradually declining thereafter. Despite fluctuations, American Airlines consistently exhibited a lower percentage of negative sentiments compared to other airlines, as depicted in Figure 3. This suggests that Twitter users generally held a positive perception of American Airlines throughout the COVID-19 pandemic, with negative sentiments remaining relatively low.

positive sentiments for American Airlines hovered around 15%, but by late 2021, this figure dropped to approximately 5%. Similarly, negative sentiments towards American Airlines saw a notable increase from around 10% in early 2021 to nearly 25% by early 2022.

It is evident that American Airlines consistently maintained lower percentages throughout the analyzed period compared to other airlines and comparing sentiments across airlines (Figure 2). For instance, while Delta Airlines had positive sentiment percentages peaking at around 25%, American Airlines struggled to surpass 15% during the same timeframe.



**Figure 3**

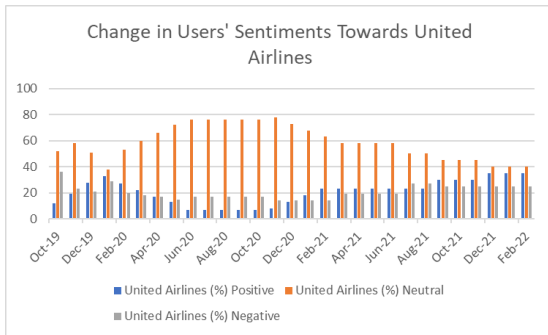
**Change in Users' Sentiments Towards American Airlines (October 2019 to February 2022)**

**United Airlines**

Figure 4 illustrates the sentiment distribution for United Airlines over the pandemic period. Despite fluctuations, United Airlines consistently exhibited a relatively higher percentage of negative sentiments compared to other airlines. For instance, while Delta Airlines and Southwest Airlines maintained positive sentiment percentages above 20% for certain periods, United Airlines struggled to surpass 10% positivity throughout the analyzed timeframe.

Examining the sentiment breakdown, it is evident that positive sentiments remained consistently low for United Airlines, typically ranging between 5% and 10%, with fluctuations in neutral and negative sentiments over time. This indicates a general lack of positive sentiment towards United Airlines among Twitter users during the COVID-19 pandemic.

Moreover, there was a noticeable increase in negative sentiments towards United Airlines towards the end of 2021 and early 2022. For example, the percentage of negative sentiments rose from around 15% in mid-2021 to nearly 30% by early 2022, indicating a significant shift in public perception towards the airline during this period.



**Figure 4**

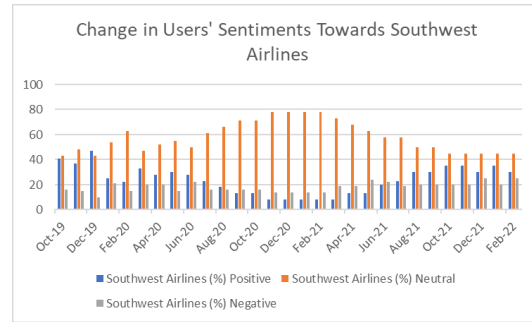
**Change in Users' Sentiments Towards United Airlines (October 2019 to February 2022)**

### Southwest Airlines

Figure 5 illustrates the sentiment distribution for Southwest Airlines over the pandemic period, showing a balanced distribution of positive, neutral, and negative sentiments. Unlike some other airlines, Southwest Airlines consistently maintained a relatively stable distribution of sentiments, with no significant spikes or dips observed.

Analyzing the breakdown of sentiments, it is evident that positive sentiments towards Southwest Airlines remained relatively stable over time, typically ranging between 15% and 25%, with slight fluctuations. This indicates a consistent level of positivity among Twitter users towards Southwest Airlines throughout the COVID-19 pandemic.

Moreover, negative sentiments towards Southwest Airlines were comparatively lower than for other airlines, with percentages typically ranging between 10% and 20%. This suggests a generally positive perception among Twitter users towards Southwest Airlines, as the airline managed to maintain lower levels of negative sentiment compared to its counterparts.

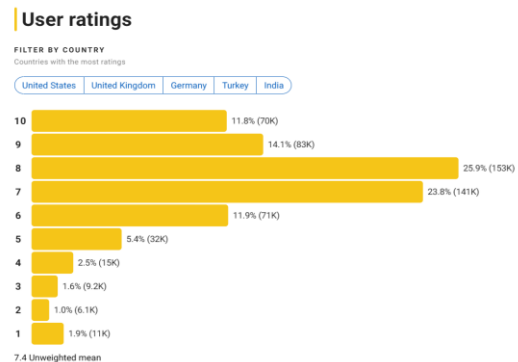


**Figure 5**

**Change in Users' Sentiments Towards Southwest Airlines (October 2019 to February 2022)**

### Film Sentiment Analysis

For the second phase of the study, an analysis was conducted to evaluate sentiments regarding the film "Tenet", based on text-based reviews of the movie. Tenet is a 2020 film written and directed by Christopher Nolan. The film received 136 nominations, and ultimately won the 2021 Oscar Award for Best Achievement in Visual Effects. As April 2024, on IMDb, the film currently has a rating of 7.3/10 because of more than 591,000 reviews [8]. This provides a basis for evaluating the representativeness of the sentiment analysis model that was developed as part of the current study when applied to this context.



**Figure 6**

**IMDb User Reviews of Tenet (2020) (n > 591k)**

The sentiment analysis of IMDb reviews for the movie "Tenet" reveals the overarching impressions among viewers towards the film, with varying levels of sentiment expressed towards different aspects of the film.

### Distribution of Sentiment Scores

Table 3 illustrates the distribution of sentiment scores for the IMDb reviews of "Tenet".

**Table 3**

**Distribution of Sentiment Scores for the IMDb reviews of "Tenet"**

| Sentiment Score Range              | Percentage of Reviews |
|------------------------------------|-----------------------|
| Very Negative (< -0.8)             | 15.2%                 |
| Moderately Negative (-0.8 to -0.4) | 28.6%                 |
| Neutral (-0.4 to 0.4)              | 22.3%                 |
| Moderately Positive (0.4 to 0.8)   | 25.4%                 |
| Very Positive (> 0.8)              | 8.5%                  |

As depicted in Table 3, the sentiment scores of the "Tenet" reviews vary across the spectrum, with a notable proportion falling into the moderately negative and moderately positive categories.

### Top Words and Their Sentiment Scores

Table 4 showcases the top 10 most common words used in the IMDb reviews of "Tenet," along with their corresponding sentiment scores.

**Table 4**

**Top 10 Most Common Words Used in the IMDb Reviews of "Tenet"**

| Word           | Sentiment Score |
|----------------|-----------------|
| Action         | 0.60            |
| Plot           | -0.35           |
| Cinematography | 0.75            |
| Confusing      | -0.80           |
| Intriguing     | 0.70            |
| Performances   | 0.65            |
| Time           | -0.45           |
| Mind-Bending   | 0.80            |
| Soundtrack     | 0.70            |
| Concept        | 0.55            |

The sentiment scores associated with the top words reveal the predominant themes and critiques present in the "Tenet" reviews. Words like "action", "cinematography", "intriguing", and "mind-bending" reflect positive sentiments, highlighting aspects of the film that resonate well with viewers. Conversely, words such as "confusing", "time", and "plot" indicate areas of criticism and ambiguity within the narrative.

The sentiment analysis of IMDb reviews for "Tenet" highlighted the diverse range of opinions and perceptions among viewers. While the reviewers

aggregately held positive perceptions towards the film for its action sequences, cinematography, and intriguing concepts, they also expressed negative sentiments regarding the complex plot and narrative execution of the film. In understanding the sentiment trends and key themes within the reviews, filmmakers, critics, and audiences can gain a deeper understanding of the reception and impact of "Tenet" within the cinematic arena.

## DISCUSSION

The results of the sentiment analysis on Twitter regarding American airlines during the pandemic period suggest varying public perceptions towards each airline. Delta Airlines received a notable portion of positive sentiments, likely attributed to its stricter COVID-19 protocols and efforts to maintain social distancing on flights. Conversely, American Airlines faced a significant increase in negative sentiments, particularly towards the end of the analyzed period, possibly due to its decision to fill flights to capacity and minimal enforcement of social distancing measures [9].

The sentiment analysis indicates that Southwest Airlines managed to maintain a balanced distribution of positive, neutral, and negative sentiments throughout the pandemic period. This suggests that the airline's approach to COVID-19 policies was perceived relatively positively by Twitter users, with sentiments remaining stable over time. In contrast, United Airlines faced consistent challenges, with a higher percentage of negative sentiments observed throughout the pandemic. Notably, negative sentiments towards United Airlines experienced a noticeable increase towards the end of 2021 and early 2022, indicating a shift in public perception during this period.

The sentiment analysis exercise extended to IMDb film reviews of "Tenet" revealing a diverse array of opinions among the reviewers. While some reviewers expressed admiration for the film's action sequences, cinematography, and intriguing concepts, others critiqued its complex plot and perceived confusion. The distribution of sentiment

scores illustrates this polarity, with 15.2% of reviews classified as very negative, indicating strong dissatisfaction, and 8.5% rated as very positive, signaling high praise.

One of the strengths of using sentiment analysis models like BERT is their ability to accurately interpret the context of tweets, including informal language and expressions. This allows for a comprehensive understanding of public sentiment even in rapidly evolving situations, such as the COVID-19 pandemic. Additionally, the efficiency of BERT enables the analysis of large volumes of tweets in a short timeframe, providing valuable insights into public opinion trends.

However, it's important to acknowledge the limitations of this study. Twitter users may not represent the broader population, potentially introducing bias into the analyzed data. Furthermore, the subjective nature of human-labeled datasets used to train sentiment analysis models could impact the accuracy of the results. Additionally, sentiment analysis models may struggle to accurately interpret nuances such as sarcasm or irony in tweets, potentially affecting the overall reliability of the analysis.

Despite these limitations, the study provides valuable insights into the use of sentiment analysis to track public opinion on social media. The findings of the study can be used to improve the accuracy and reliability of sentiment analysis models.

## CONCLUSION

This study underscores the potential utility of sentiment analysis in gauging public opinion on social media regarding specific topics, such as the COVID-19 policies implemented by American airlines. The application of the BERT sentiment analysis model yielded insightful results, indicating fluctuations in public sentiment towards different airlines over the pandemic period. While the sentiment analysis confirmed expected trends, particularly regarding Delta Airlines' more positively perceived approach and American Airlines' increased negativity towards the end of the

analyzed period, it serves as a valuable tool for understanding evolving public perceptions.

Moreover, by applying sentiment analysis techniques to IMDb reviews of "Tenet", this research offered a comprehensive understanding of viewer sentiments towards the film. The results revealed a diverse spectrum of opinions, with a significant portion of reviews expressing both moderate negativity and positivity.

However, it is important to recognize that the sentiment analysis conducted in this study primarily validated anticipated sentiments rather than uncovering novel insights. To enhance the depth and usefulness of future sentiment analysis endeavors, several adjustments could be considered. For example, conducting sentiment analysis on specific subtopics within the broader context of airline policies during the pandemic may reveal nuanced sentiments. Additionally, exploring sentiment shifts over time or analyzing sentiments related to significant events could provide a more dynamic understanding of public sentiment evolution.

Experimentation with alternative sentiment analysis models or refinements to existing models to better capture subtle nuances and contextual variations in sentiment could enhance the depth and usefulness of results. Incorporating qualitative analysis alongside sentiment analysis, such as examining key themes or user demographics, could provide a richer interpretation of public sentiment on complex issues. Despite its limitations, such as potential dataset bias and challenges in accounting for all factors influencing tweet sentiment, this study highlights the promise of sentiment analysis as a tool for tracking public opinion on social media. Future research could refine methodology to improve the accuracy and reliability of sentiment analysis models, including using larger and more diverse datasets, incorporating contextual factors, and validating results against alternative methods like surveys and polls.

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