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Deciphering Tourism's Role in Antarctica's Geosocial Concerns through Data Mining Techniques

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Abstract: This study explores the changing dynamics of tourism in Antarctica, focusing on the impact of digitalisation and User-Generated Content on platforms like Tripadvisor. It aims to understand how online reviews influence perceptions and decisions to visit Antarctica, a region known for its pristine environment and status as 'the last frontier'. Utilising Environmental Perception and Behaviour Geography (EPBG) principles, this research conducts a quantitative analysis of reviews from potential and current travellers. Through text mining, topic modelling, sentiment analysis, and Natural Language Processing (NLP), it investigates the emotional and perceptual discourse surrounding Antarctic tourism and its alignment with Agenda 2030 and Sustainable Development Goals. The findings reveal a detailed narrative of sustainability challenges and the emotional geography related to tourism in Antarctica, highlighting emotions such as happiness, anger, surprise, fear, disgust, and sadness among visitors. This study uncovers differences in perception based on visitors' backgrounds, noting that individuals from nature-focused cities display strong environmental concerns, whereas those from advanced urban centres show a more positive attitude. This research contributes to the understanding of EPBG, text mining, and NLP, offering insights into sustainable tourism practices in Antarctica.

Keywords: Antarctica tourism; Tripadvisor; topic modelling; sustainable tourism; Agenda 2030; Sustainable Development Goals



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1. Introduction

Antarctica, owing to its exceptional isolation and pristine natural state, emerges as a fascinating destination for those individuals seeking to immerse themselves in authentic experiences and feel the urge to distance themselves from conventional and overcrowded destinations [1]. It has been observed that certain individuals manifest a strong desire to explore and embark on adventures in environments considered extreme or inhospitable for human life [2]. These motivations may coexist or intertwine with others, such as interest in the history and politics of Antarctica, as well as the allure of this sixth continent, considered by many as 'the last frontier' [3]. From a psychological perspective, journeys to Antarctica offer a platform for the development of greater environmental sensitivity and awareness, personal growth, and overcoming challenges [4]. Its extreme geography and climate can demand a level of physical and mental resilience that few destinations require. Changing perceptions of safety, improved access to the region, and the growing global travel economy also contribute to Antarctica becoming progressively less unknown [5]. However, the perceptions of visitors to Antarctica have not been utilised to identify current and future sustainability dynamics in tourism for this territory, despite its high ecological vulnerability [6] conditioned by anthropogenic-related factors in social, economic, and environmental terms.

While this premise of endogenous motivations and concerns has existed for decades, the current context is transforming the relationship with the continent. Today, strong digitalisation and the proliferation of User-Generated Content on the Internet are altering the landscape [7]. The desire to ‘tick off countries’ and the influence of forums and social networks have emerged as significant catalysts in choosing Antarctica as a destination [4]. There has been a growing influence of these platforms in shaping social perceptions, promoting economic and social development, and in decision-making across various fields, including tourism. In particular, the Tripadvisor platform (the world’s leading travel forum) has emerged as a crucial and globally recognised resource for seeking information and making travel decisions [8].

Environmental Perception and Behaviour Geography (EPBG) focuses on understanding issues related to human behaviour, perception, attitudes, beliefs, memory, language, intentions, reasoning, and problem-solving concerning space and place, delving into the complex interplay of factors that shape environmental interactions [9] since it was initially suggested in the 1960s [10,11]. In the context of Antarctic tourism, the application of EPBG principles becomes paramount. The pristine and vulnerable nature of Antarctica’s ecosystems, coupled with the unique experiences of tourists, necessitates a nuanced understanding of environmental perception and behaviour. Thus, the aim of this study is to conduct a quantitative analysis of EPBG concerns derived from reviews by potential and current travellers embarking on a journey to Antarctica. To do so, data mining techniques were used, specifically topic modelling and sentiment analysis, within the realm of Natural Language Processing (NLP).

In recent years, the field of EPBG has increasingly recognised the importance of integrating advanced analytical techniques to better understand the dynamic interplay between human perceptions, behaviours, and environmental contexts. This study introduces a novel application of EPBG principles to the understudied and ecologically sensitive context of Antarctic tourism. Prior research has primarily focused on more accessible and less extreme environments, often overlooking the unique challenges and opportunities presented by such remote locations as Antarctica [12,13]. Furthermore, traditional EPBG studies have not fully leveraged the potential of digital User-Generated Content to capture real-time, authentic tourist perceptions and behaviours [14,15].

The study of EPBG has been pivotal in understanding the intricate ways in which human behaviours and perceptions are shaped by the environment. This paper seeks to apply EPBG to the unique and extreme environment of Antarctic tourism, a context that poses distinct challenges for sustainable tourism practices. Foundational to this field, Lowenthal [10] and Weightman [11] laid the groundwork for EPBG by exploring how environmental interactions are influenced by human perceptions and behaviours. These seminal works underline the importance of considering multiple human factors—such as attitudes, beliefs, and problem-solving—within specific environmental contexts. Building on this foundation, our study aims to delve deeper into the dynamics of tourist interactions with the Antarctic environment, a locale that, until now, has seen limited exploration within this theoretical framework.

Recent advancements in EPBG have shown a promising alignment with sustainability goals, especially within tourism contexts. For instance, Knaap [16] and Gupta et al. [17] have expanded the application of EPBG principles to explore how tourists’ environmental responsibilities are influenced by their perceptions and experiences in eco-sensitive zones. These studies demonstrate the potential of EPBG to foster sustainable tourism practices by enhancing tourists’ awareness and behaviours towards the environment. By integrating these contemporary insights with advanced data analysis techniques, this study seeks to offer a nuanced understanding of the emotional and perceptual responses of tourists in Antarctica. This approach not only enriches the theoretical landscape of EPBG but also contributes practical insights towards managing tourism sustainably in one of the world’s most vulnerable ecosystems.

This paper extends the theoretical and methodological frameworks of EPBG by incorporating cutting-edge data mining techniques, including sentiment analysis, topic modelling, and Natural Language Processing (NLP). These methods are employed to analyse a rich dataset of User-Generated Content from Tripadvisor, offering a comprehensive view of the emotional and cognitive responses of tourists to Antarctica. This approach allows for a more nuanced understanding of environmental perceptions that are influenced by digital interaction, a dimension scarcely addressed in previous studies [18]. By doing so, this research not only broadens the applicability of EPBG to extreme environments but also connects these theoretical insights with the practical challenges of promoting sustainable tourism practices in line with Agenda 2030 and the Sustainable Development Goals (SDGs). This integration of digital ethnography and geographical theory represents a significant step forward in how researchers can explore and interpret complex environmental interactions in tourism studies.

While there is notable previous work using Tripadvisor as a data source [19,20], this research is pioneering and innovative, as it is the first to use the Online User-Generated Content of this platform in relation to inhospitable adventure environments such as Antarctic lands. This includes content specifically from the “Antarctic Adventures Forum” and the review section “Things to Do in Antarctica” as a source and database for conducting several analyses. For the first time, these data have been used to create a topic modelling analysis to gain a deeper understanding of the relationship between this continent, its current and potential visitors, the tourism industry, and Agenda 2030 and the 17 Sustainable Development Goals.

Regarding the structure of this work, after the introduction, Section 3 is devoted to the methodology applied, while Section 4 presents the results and discussion. Finally, Section 5 presents the conclusions of the work.

2. Materials and Methods

This study advances the application of User-Generated Content (UGC) and Natural Language Processing (NLP) techniques by specifically focusing on the unique context of Antarctic tourism, a subject that has not been extensively explored in previous research. Employing traditional methods like word segmentation and Latent Dirichlet Allocation (LDA) for topic modelling, this research integrates these with advanced techniques such as the Valence Aware Dictionary for Sentiment Reasoning (VADER) and SentiART to delve into the nuanced emotional dimensions of tourist experiences. This novel methodological combination, alongside the application of Environmental Perception and Behaviour Geography (EPBG) principles, allows for an in-depth analysis of how tourist perceptions and behaviours impact the sustainability of Antarctic tourism. This study not only fills a significant gap by linking tourist behaviour with the Sustainable Development Goals (SDGs) but also enhances our understanding of the dynamic interplay between tourists and the extreme environment of Antarctica [14,21].

Furthermore, by examining the temporal evolution of tourist sentiments and the influence of tourists’ cities of origin, this study adds new layers of understanding to the existing body of research on tourist perceptions. These insights are crucial for developing targeted sustainable tourism strategies in Antarctica, aligning with specific SDGs such as SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 14 (Life Below Water). The interdisciplinary approach, blending advanced NLP with EPBG within the theoretical framework of sustainable tourism, provides actionable insights that can guide policy and operational decisions in managing one of the world’s most sensitive and rapidly changing tourism destinations [9–11,22].

Figure 1 summarises the methodology that will be explained in detail. The research process begins with data collection from Tripadvisor, followed by data pre-processing, cleaning, and text pre-processing techniques. This study then conducts topic modelling using LDA, creates a thesaurus to identify sustainable dimensions (economic, social, and environmental), and performs sentiment analysis using VADER and SentiART. The tempo-

ral evolution of sentiments and the influence of tourists' cities of origin are also explored. The results are interpreted and discussed in the context of Antarctic tourism sustainability, highlighting theoretical contributions to EPBG and identifying research gaps. Finally, this study concludes by summarising the main findings, discussing implications for sustainable Antarctic tourism, and proposing future research directions.

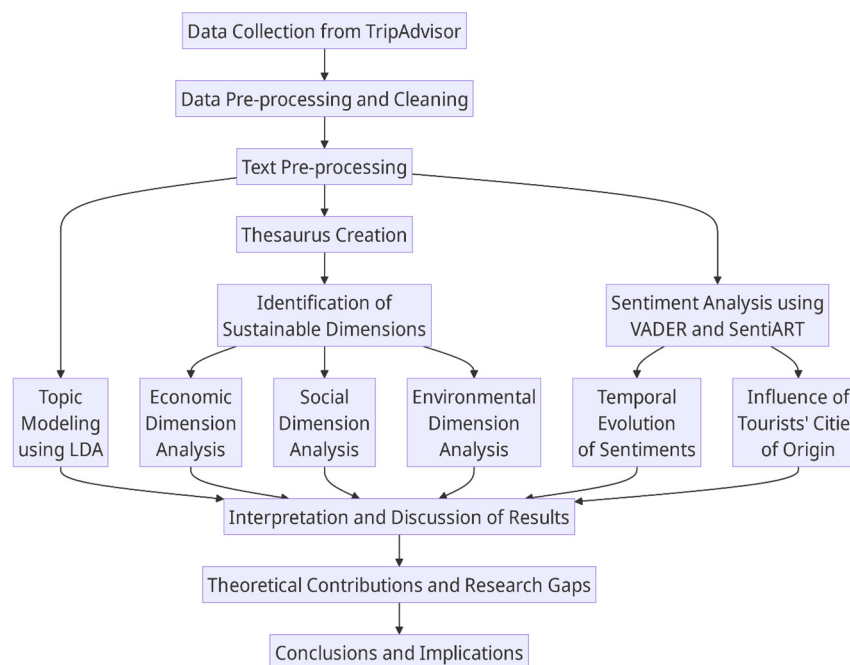


Figure 1. Summary of the methodology employed.

2.1. Data Source and Collection

Selected Data (Temporal, Spatial and Category Scope)

The current research employs Online User-Generated Content (UGC) to assess Antarctica as a travel destination. The adoption of UGC for destination evaluation has become increasingly prominent in recent times [23,24]. In a similar vein, sentiment analysis has been widely recognised as an effective tool in tourism studies for destination appraisal [18,25]. For conducting the sentiment analysis, this study utilises an open-source platform that leverages Python libraries dedicated to scientific computing. This platform provides access to a range of functionalities including data analysis and mining, sentiment analysis, and topic modelling.

Tripadvisor, founded in 2000, has evolved into a leading platform offering extensive data and insights into the global travel and tourism industry. The platform aggregates and displays user reviews and ratings, allowing travellers to share their experiences and opinions on a wide range of travel services and destinations. This User-Generated Content is the cornerstone of Tripadvisor's service, offering detailed, real-world insights into the quality, service, and overall experience of travel around the world. These include forums where users can ask questions and share advice, and a Trip Planner feature for organising and saving ideas for future travels.

Employing web scraping techniques, various datasets were compiled, encompassing a wide array of reviews. This comprehensive data collection included all available reviews (845) from the Tripadvisor forum on Antarctica, spanning from January 2012 to February 2024. These reviews provided an extensive and diverse range of insights and experiences from travellers, offering a rich source of information for analysis.

The dataset is centred on attributes pertaining to guest feedback within the outlined categories. Key variables considered include the quantity of comments, their dates, and the comments themselves (which were automatically converted to English when downloaded

to facilitate universal comprehension). Furthermore, a novel variable was introduced in some datasets: the initial language of the comment, determined by a Google Sheets function that ascertains the language from a specific text sequence.

The variable 'language' denotes the primary language used in the visitor's critique. Comprehending the variety of languages represented in the critiques offers valuable insights into the heterogeneity of the visitors, aiding in the formulation of strategies to tailor communication and marketing initiatives to suit diverse linguistic and cultural contexts.

2.2. Text Pre-Processing and Cleaning

Data pre-processing plays a pivotal role in all data analysis endeavours. This process entails the meticulous cleaning and structuring of the dataset, a necessary step to guarantee its appropriateness for subsequent analytical procedures [26]. This research utilised elementary techniques for NLP and data processing concentrated on pinpointing and measuring subjective details within texts [27].

The methodology for sentiment analysis was structured into several consecutive stages. The initial stage involved cleansing and standardising the data, which entailed extracting textual reviews from the Tripadvisor collaborative platform. During this phase, the languages present were identified, followed by an automated translation of all content into English, the predominant language, to ensure consistency in analysing the reviews for equitable comparison. Subsequently, the textual content was divided into sentences and further into tokens. Tokenisation is the process of breaking down the text into smaller elements, such as words and punctuation. The next step involved part-of-speech tagging (PoS tagging), a process that classifies words into their grammatical categories based on their definitions and context. For instance, in the phrase "the restaurant is great", 'restaurant' is categorised as a noun, while 'great' is an adjective.

The analysis then progressed to lemmatisation, a step where words are transformed to their base or root form, and all opinions are converted to lowercase. The objective of lemmatisation is to simplify words to their lemma or most fundamental form. For example, variations like 'runs', 'running', and 'ran' are all reduced to the root word 'run'.

The final stage of the study involved the incorporation of a list of stop words, such as 'the', 'and', or 'other'. These words, often irrelevant in sentiment analysis and topic modelling, can skew the interpretation and outcomes of the textual analysis.

2.3. Topic Modelling

As we explore the Environmental Perception and Behaviour Geography of Antarctic tourists, we unravel the layers of their experiences, motivations, and interactions with the icy continent. EPBG principles guided our inquiry into the impact of culture on tourists' environmental attitudes, the socioeconomic factors influencing travel choices, and the educational potential of Antarctic tourism. Furthermore, the interdisciplinary nature of EPBG facilitates a holistic understanding of the challenges posed by tourism in Antarctica, ranging from climate change awareness to the preservation of fragile ecosystems.

This research applied Latent Dirichlet Allocation (LDA) for topic modelling. Recognised as a technique in topic modelling, LDA excels in detecting the hidden patterns of words and themes across a document set [28]. As a generative probabilistic model, LDA conceptualises each document as a blend of multiple topics, with each topic comprising a set of words assigned different probabilities.

The LDA algorithm leverages Dirichlet distributions to effectively map the topic distribution within documents and the word distribution across topics. Implementing LDA enabled us to achieve a succinct and clear depiction of the themes in the corpus, significantly simplifying the process of comprehending and examining extensive textual data.

2.4. Thesaurus

We crafted an extensive and suitable thesaurus, abundant with a variety of synonyms that encapsulate the various aspects of sustainable development. This was undertaken with

the aim of utilising Natural Language Processing (NLP) to identify keywords and assess the incidence of the dimensions of sustainable development, namely social, economic, and environmental. This work represents a unique, distinctive, and significant addition to scholarly discourse. For this compilation, we employed the digital version of the Encyclopaedia Britannica, highly esteemed in the realm of English language resources [29], in conjunction with the Oxford Thesaurus of English. We also consulted Roget's Thesaurus to include further synonyms pertaining to the three dimensions of sustainable development, thereby refining the thesaurus prior to its integration into our analytical software, Orange version 3.36.1 [30].

This thesaurus encompasses six major categories (abstract relations, space, matter, intellect, volition, and affections), structured like a tree with over a thousand branches, each grouping words with similar meanings or 'clusters of meaning'. The entries in Roget's Thesaurus, while not always perfectly synonymous, serve effectively as variations or shades of a concept, encompassing a range of related ideas. Recognised for its effectiveness in assessing semantic resemblance, Roget's Thesaurus has proven invaluable; while the formation of lexical chains is somewhat straightforward, their analysis poses more complexity [30]. This approach enabled us to produce a balanced final word list, evenly spread across the three foundational dimensions of sustainable development.

The selection of keywords for each sustainability dimension in our study was guided by the specific focus and scope of that dimension, as well as the nature of the User-Generated Content being analysed. In the social dimension, the inclusion of actors such as "community", "volunteers", and "researchers" reflects the emphasis on the human and interpersonal aspects of Antarctic tourism experiences, capturing the social interactions, collaborations, and roles that shape tourists' perceptions and behaviours [5]. The economic dimension features keywords such as "expensive", "purchases", and "souvenir", representing the financial and transactional aspects inherent in the tourism experience, from travel costs to the acquisition of goods and services [31]. For the environmental dimension, broad aspects like "impact", "preservation", and "climate change" were deliberately chosen to capture the wide range of environmental issues and concerns relevant to Antarctic tourism, given the fragile and sensitive nature of the Antarctic ecosystem [32].

While the chosen keywords across the three dimensions may not be directly comparable in terms of their specificity or nature, they are representative of the key aspects and considerations within each dimension. The aim of this analysis is to provide a comprehensive understanding of how each dimension is reflected in the User-Generated Content and how it contributes to the overall perception and experience of Antarctic tourism. To ensure the robustness and validity of our analysis, we employed a rigorous methodology that combines topic modelling, sentiment analysis, and Natural Language Processing techniques, allowing us to identify the most salient and meaningful patterns and themes within the User-Generated Content, regardless of the specific nature of the keywords used [33].

Leveraging these varied thesauri, our program identifies pertinent reviews and assigns them significance within the dimension of the framework. For example, Table 1 showcases a range of words gathered from each dimension, and Table 2 demonstrates examples of these reviews.

Table 1. Examples of words included in the thesaurus representing each dimension of sustainable development.

Economic Sustainability	Social Sustainability	Environmental Sustainability
Expensive	Community	Impact
Purchases	Volunteers	Preservation
Souvenir	Researchers	Climate change

Own elaboration.

Table 2. Examples of reviews representing each dimension.

Dimension	Review
Economic	<i>“The prices are somewhat higher than typical souvenir shops, but considering how difficult it is to transport the merchandise onto the island and into the shop, they are quite reasonable”.</i>
Social	<i>“Amazing, a post office, a shop, a radio station and a pub, it has it all. This place will stay in my memories forever and one day I will go back. If I was able I would volunteer to work here for the summer months”</i>
Environmental	<i>“What a sight to behold this pristine, surreal environment which on most occasions looks undisturbed. From the glaciers to the wildlife, this majestic place has history and is a photographer’s dream with beautiful sights around every corner. This is a must for those that love nature, wildlife and for those that want to feel free and alive”.</i>

Own elaboration.

2.5. Sentiment Analysis and Data Mining

This study utilised the “Valence Aware Dictionary for Sentiment Reasoning” (VADER), a sentiment analysis tool, model, and lexical database [34]. VADER, a rule-based system, is specifically optimised for analysing sentiments in User-Generated Content. This tool automatically categorises each word in the lexicon, whether in English or translated to English, as positive, neutral, or negative. It not only assigns scores to these words but also quantifies the extent of positivity or negativity [35].

VADER builds upon established sentiment lexicons that incorporate lexical attributes commonly used in social media expressions. Its lexicon comprises over 7500 terms, including slang, acronyms, and emoticons. VADER integrates sentiment analysis modules from the Natural Language Toolkit (NLTK) library in Python.

It analyses the sentiment of each comment, assigning scores from -1 for negative to 1 for positive sentiments. VADER is widely recognised as a benchmark in social media sentiment lexicons [36].

Alongside VADER, this study also incorporates SentiART, a multifaceted sentiment analysis tool (SAT). SentiART is capable of computing four lexical features—arousal, emotion potential, valence, and aesthetic potential—and two inter-lexical features, namely valence span and arousal span. Its primary function is to predict various dimensions related to the sentiment distribution in a text [37].

3. Results

3.1. Topic Modelling

The results of this work enable the construction of a comprehensive dialogue on sustainability, starting from the key issues raised by actual and potential visitors to Antarctica. This process identifies an interrelation of topics arising from the topic modelling process (Table 3) and challenges that become crucial within the framework of Agenda 2030, concerning two different pillars: (1) temporal and spatial perception of Antarctic tourism; and (2) behavioural patterns in the Antarctic tourism landscape.

Table 3. Topic modelling following the LDA method.

Clusters	Topic Keywords
Geography:	<i>antarctica, patagonia, antarctic, stanley, south georgia, falkland islands, brazil, buenos aires, australia, nz, ush, argentina, puerto Williams</i>
Expeditions and Travels:	<i>icebreaker, khlebnikov, travel, quest, journey, trip, expedition, adventure, tour, cruise, voyage, crossing, excursion, itinerary, trekking, journey, visit, trips, travel, excursion, tour, journey, voyage, travels, safari, travel</i>

Table 3. Cont.

Clusters	Topic Keywords
Time and Calendar:	<i>march, february, october, january, december, time, day, month, season, year, dates, times, november</i>
Equipment and Preparations:	<i>map, packing, list, boots, shoes, luggage, equipment, gear, backpack, dslr, camera, binoculars, accessories, sunglasses, gloves, goggles, shoes, boots, clothes, luggage, clothes</i>
Nature and Environment:	<i>wildlife, penguins, ice, snow, cold, weather, horizon, sun, penguins, weather, ice, snow, sun, weather</i>
Travel Companies and Operators:	<i>company, lindblad, agent, chimu, polar, national geographic, intrepid, antarpply, resolute, dap, linblad, antarpply, akedemik, antarpply, ms expedition, quark, g adventures, ponant, hapag lloyd, gadventure</i>
Activities and Experiences:	<i>experience, kayaking, camping, photography, hiking, skiing, zodiac rides, sailing, boarding, skiing, landing</i>
Transportation and Vehicles:	<i>ship, passenger, vessel, airline, zodiac, deck, cabin, ship, airline, boat, zodiac, cabin, airplane, ship, airline, boats, aircraft, cabin, ship</i>
Accommodation:	<i>hotel, cabins, rooms</i>
Insurance and Policies:	<i>insurance, policies, cancellation, refund, deposit, policy</i>
Documentation and Legality:	<i>passport, visa, tickets, passports</i>
People:	<i>family, men, kids, passengers, citizens, researcher</i>
Technology and Electronics:	<i>net, electrical, sockets, storage, device, gopro, electronics, storage, device, satellite</i>
Health and Safety:	<i>medical, evacuation, COVID, safety, emergency</i>
Communication:	<i>review, information, report, blog, feedback, reviews, report, post, advice, review, news, advice, reviews, information</i>
Finance:	<i>cost, money, price, budget, fee, prices, money, cost, budget, fee</i>
Bookings and Sales:	<i>offer, sale, book, booked, booking, reservation, booking, reservations</i>
Clothing:	<i>jacket, pants, shoes, gloves, dress, boots, clothes, boots, jackets, pants, shoes, gloves</i>
Camera and Photography Equipment:	<i>lenses, camera, bags, photographers, camera, photography, photos, camera, photography, photos, camera</i>
Miscellaneous:	<i>conditions, extreme, double, check, close, end, charter, carry, soleal, power, double, check, wait, pichu, delete, limit, flights, checklist, check</i>

Own elaboration.

3.1.1. Temporal and Spatial Perception of Antarctic Tourism

Spanning diverse geographical landscapes, including Antarctica, Patagonia, the Falkland Islands, South Georgia, and the pivotal gateway city of Stanley, the results of the topic modelling incorporate perspectives from a spectrum of traveller origins (Brazil, Australia, New Zealand, Argentina, and Chile). However, expanding the geographical scope to include interconnected regions adds complexity and requires managing the broader impact on interconnected ecosystems and regions requires effective coordination and cooperation among diverse stakeholders, including different nations, tour operators, and regulatory bodies. This aligns with Sustainable Development Goal (SDG) 17 (Partnerships for the Goals), emphasising the necessity for collaborative efforts to address complex global challenges in Antarctic tourism, in line with one of the challenges identified by Vila et al. [38].

Moving into the temporal dimension, the critical facet of Antarctic tourism conversations emerges with explicit references to months, days, and times. This temporal sensitivity reflects a heightened awareness of the seasonal nuances of the Antarctic environment, providing valuable insights into how tourists actively engage with and contribute to the

region's cyclic rhythms. Specific attention to the month of November emphasises its significance in the context of tourist interactions, potentially linked to distinct environmental conditions, wildlife behaviours, or specific expeditionary activities. This temporal sensitivity provides valuable insights into how tourists engage with and contribute to the broader seasonal rhythms of the region, demanding careful management to prevent disturbances to wildlife and ecosystems. The delicate task of balancing year-round tourism desires with the imperative of preserving the Antarctic environment emerges as a crucial challenge. Thus, from this topic modelling output, the need to manage seasonality is confirmed, consistent with other studies [5,39].

Turning to the modes of transportation, the incorporation of eco-friendly options, like Zodiacs and sailing, underscores a commitment to minimising the carbon footprint and fostering sustainable mobility practices within the region. Also, the association with the *Khlebnikov* underscores a commitment to advanced icebreaker technologies, aligning with SDGs 7, 11, 13, and 14 on Climate Action and sustainable practices on land and below water. Collectively, these findings paint a comprehensive picture of Antarctic tourism's conscientious evolution, highlighting the synergy between sustainable practices and SDGs. This nuanced understanding is crucial for shaping future policies and practices in Antarctic tourism, ensuring a harmonious alignment with global sustainability imperatives. Additionally, technological considerations (cluster 13), encompassing "electrical sockets", "storage devices", and "satellite technology", unfold the evolving technological landscape of Antarctic tourism.

The discussion around technological and mobility aspects reflects the sector's commitment to staying abreast of innovations while ensuring Responsible Consumption and Production practices. However, one of the main challenges in this context is to ensure that technological advancements prioritise sustainability, minimising the environmental footprint and adhering to Climate Action goals [40,41].

3.1.2. Behavioural Patterns on Antarctic Tourism Landscape

Transitioning to the behaviours of Antarctic tourists, a discerning approach to packing is evident, as meticulous lists are crafted to include eco-friendly essentials. This practice attests to a conscientious embrace of SDG 12, highlighting a cognisant shift toward Responsible Consumption and Production. Simultaneously, the thematic focus on wildlife encounters (cluster 5), with explicit mentions of "penguins", "ice", "snow", and other natural elements, underscores alignment with SDGs 14 and 15. These references emphasise the role of responsible tourism in preserving both marine life and terrestrial ecosystems, emphasising environmental conservation within the unique Antarctic context.

Moreover, the diverse array of tour operators, ranging from Lindblad and Chimu to National Geographic and Antarpplly, signifies economic relevance, aligning with SDGs 8 and 9. This underscores the imperative for sustainable and responsible practices, ensuring that industry growth and infrastructure development resonate with global sustainability goals. Furthermore, the discourse on experiential activities (cluster 7) such as "kayaking", "camping", "photography", and "sailing" harmonises with SDGs 7, 11, and 14. The emphasis on eco-friendly experiences reflects a commitment to sustainable energy practices, responsible tourism management, and conservation efforts, contributing cohesively to the broader goals of affordable and clean energy, sustainable cities and communities, and Life Below Water.

In addition, topics encompassing (cluster 2) "wildlife safaris", "trekking", and "visits" to research stations underscore a commitment to the preservation of marine and terrestrial ecosystems, aligning with the overarching objectives of these SDGs. The extensive use of an expeditionary lexicon (cluster 2), including terms like "journey", "adventure", "tour", "cruise", "voyage", and "travel", captures the diverse and immersive nature of Antarctic tourism experiences. These terms appear interconnected with booking practices, evident in terms like "offer", "sale", "booking", and "reservations", encapsulating the economic transactions and operational practices within Antarctic tourism and aligning with SDGs

8 and 12. However, a significant challenge lies in fostering the widespread adoption of such sustainable practices and cultivating a culture of responsible tourism, which can provoke deep affective responses such as awe and humility to instigate transformational outcomes that affect settings well beyond the place where the consumption occurs [42]. Thus, overcoming barriers to behaviour change and encouraging sustainable choices among a diverse range of visitors is crucial for addressing this challenge and ensuring the long-term viability of Antarctic tourism in alignment with the principles of Agenda 2030.

In essence, the main challenges for Antarctic tourism in the context of Agenda 2030 encompass effectively managing the temporal and geographical dimensions, fostering international cooperation, ensuring responsible technological advancements, and promoting a culture of sustainable and responsible tourism among visitors. Tackling these challenges is essential for Antarctic tourism to make a positive contribution to the broader global sustainability objectives outlined in Agenda 2030.

3.2. Frequency and Origins of the Reviews

Figure 2, representing the geographical distribution of traveller reviews regarding their journeys to Antarctica, provides an insightful and revealing perspective on global trends in extreme tourism. Out of the 278 cities analysed worldwide, it is noteworthy that 46.45% of the reviews originate from the United States, with New York leading at 3.03%. In Europe, the United Kingdom accounts for 21.07%, where London stands out with 6.05% of the reviews recorded on the Tripadvisor platform, making it the city with the highest number of reviews in Europe and one of the most significant globally. Hong Kong with 2.68% and Melbourne with 1.86% also emerge as notable centres, as stated in Figure 3.

The predominance of cities like New York, London, and Hong Kong in Asia can be attributed to several interrelated factors, primarily economic and sociocultural [43]. These cities are characterised as major global financial hubs, which implies a concentration of individuals with high per capita incomes [44]. This economic capacity not only facilitates access to high-cost trips, such as an expedition to Antarctica, but may also influence the tendency to share travel experiences on online platforms [45].

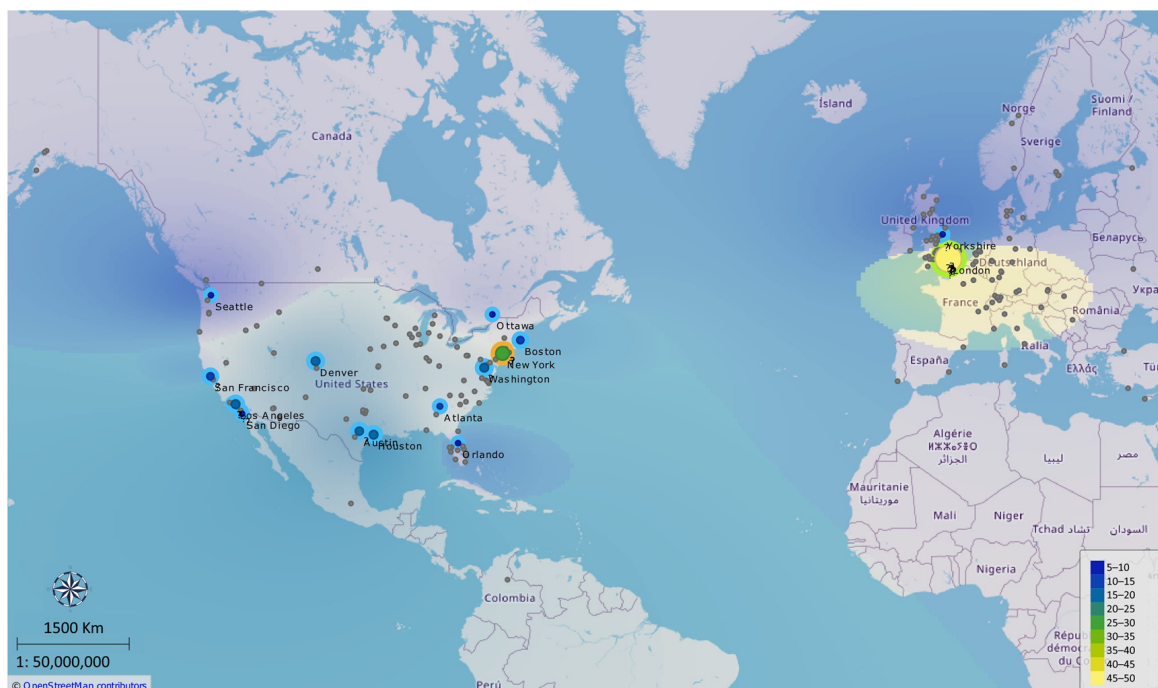


Figure 2. Frequency and origins of the reviews in Europe and North America.

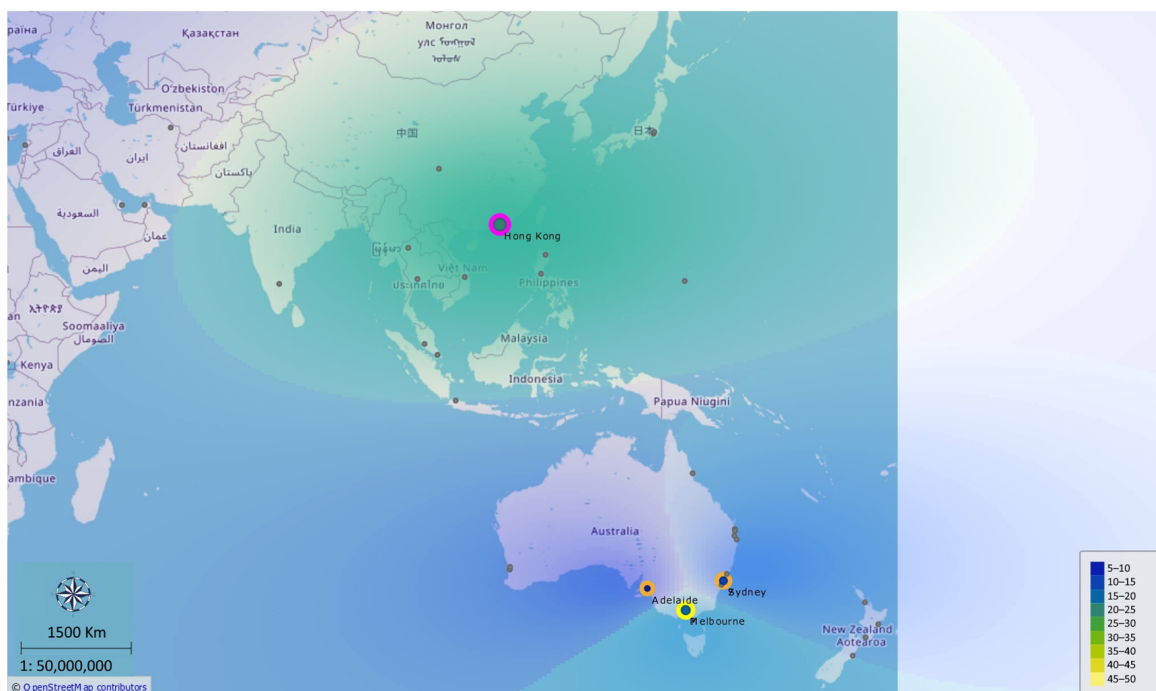


Figure 3. Frequency and origins of the reviews in Asia and Oceania.

Furthermore, these metropolises are recognised for their multicultural and cosmopolitan nature. The diversity and richness of their cultural and educational contexts create an environment that values and encourages unique and enriching experiences [46], such as travels to exotic and extreme destinations. This not only reflects global concerns and aspirations but also a desire to explore and understand environments different from one's own.

Another crucial aspect is connectivity. Cities like New York, London, and Hong Kong function as major air transport hubs [47], facilitating access to remote destinations like Antarctica. The availability of direct or few-stop air routes reduces logistical and time barriers, making these journeys more feasible for their inhabitants. Figure 3 illustrates the frequency and origins of reviews in Asia and Oceania. The areas in green and blue denote regions with a high concentration of reviews, highlighting cities such as Hong Kong and Melbourne as the primary sources. The colour scale is defined as follows: blue indicates the lowest frequency of reviews, green tones represent a moderate number, and yellow indicates the highest frequency.

Finally, the symbolic aspect of these journeys cannot be underestimated. In societies where the standard of living is high, trips to unique destinations like Antarctica can be perceived not only as an enriching life experience but also as a symbol of status and exclusivity [48,49]. This cultural factor, linked to the perception of travel as an achievement or distinction, may motivate individuals not only to undertake the expedition but also to share their experiences through platforms like Tripadvisor [50].

3.3. Thesaurus to Identify Sustainable Dimensions

3.3.1. Economic Dimension

In this research, we explore the complex landscape of traveller sentiments towards journeys to Antarctica, drawing on sentiment analysis derived from three distinct thesauri, each representing one of the key dimensions of sustainable development: economic, social, and environmental. This study focuses on travellers from China, the United Kingdom, the United States, Canada, and Australia, examining how their perceptions, shaped by the sentiments associated with these three dimensions, influence their experiences in the extreme environment of Antarctica (Figure 4).

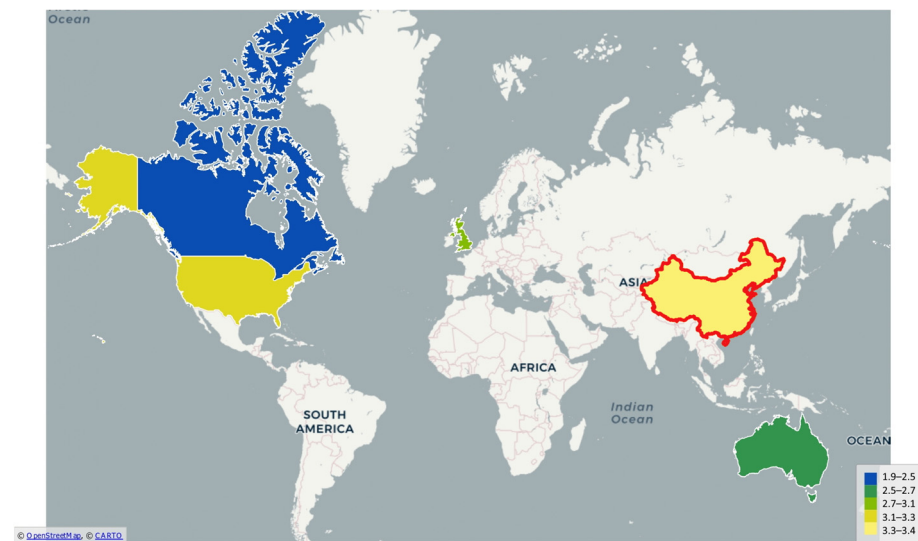


Figure 4. Data mining of the economic dimension in countries with the highest number of reviews.

The sentiment analysis reveals that perceptions rooted in the economic dimension vary significantly among these countries. For instance, travellers from economically robust nations like the United States and China exhibit sentiments of positivity and readiness for the challenges of Antarctic expeditions. In contrast, travellers from Australia and Canada, while hailing from stable economies, show a nuanced perception, likely reflecting a deeper contemplation of sustainable tourism's costs and investments.

The economic aspect plays a crucial role [51] in facilitating travellers' journeys to Antarctica. For instance, nations with substantial economic indices, such as the United States (3.08) and China (3.26), demonstrate a propensity for positive sentiments like happiness among their travellers. This implies that economic solidity provides individuals with the necessary resources and preparedness for arduous expeditions. In contrast, countries like Australia (2.48) and Canada (1.85), whilst economically stable, exhibit a more tempered approach, perhaps reflective of an enhanced consciousness regarding the costs and investments necessary for sustainable tourism. This might indicate a wider societal dedication to sustainable practices, transcending mere personal wealth [52].

This figure presents a world map highlighting the countries with the highest number of travel reviews that represent the economic dimension. On the map, China stands out as the country with the most reviews in this category. The colour scale is defined as follows: blue indicates the lowest frequency of reviews, green tones represent a moderate number, and yellow indicates the highest frequency.

3.3.2. Social Dimension

The social aspect, characterised by community cohesion and resilience, significantly impacts how travellers address and process demanding experiences. Canada (social index: 2.19) and Australia (2.47), for example, are renowned for their robust social infrastructure, presumably endowing their citizens with the necessary emotional resilience to withstand the rigours of an Antarctic expedition. This stands in marked contrast to China (1.20), where diminished levels of social cohesion could lead to a broader range of emotional experiences and perhaps less efficacious management of the challenges associated with travel [53]. This divergence highlights the criticality of social support networks and collective resilience in tackling the unique difficulties presented by extreme environments [54] (Figure 5).

This figure presents a world map highlighting the countries with the highest number of travel reviews that represent the social dimension. On the map, Australia stands out as the country with the most reviews in this category. The colour scale is defined as follows: blue indicates the lowest frequency of reviews, green tones represent a moderate number, and yellow indicates the highest frequency.

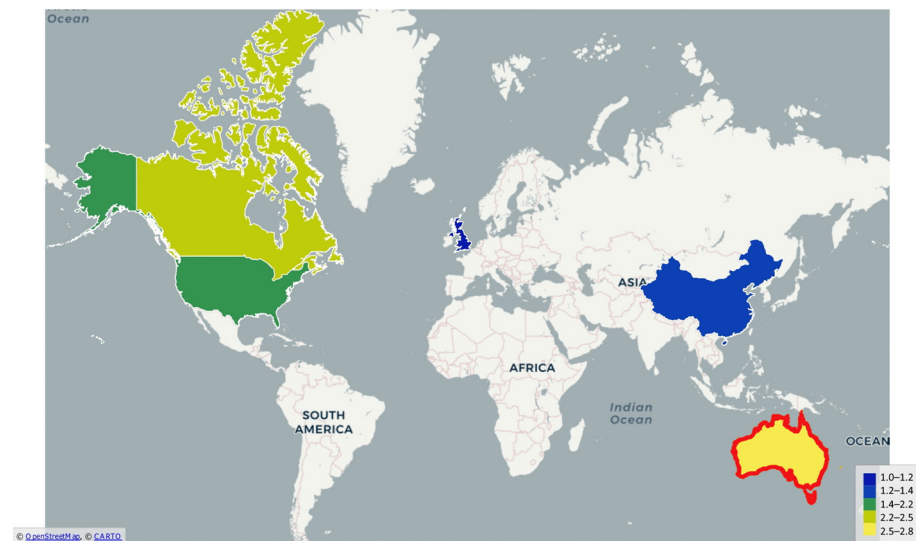


Figure 5. Data mining of the social dimension in countries with the highest number of reviews.

3.3.3. Environmental Dimension

The environmental dimension is critical in shaping perceptions of Antarctica. Countries with high environmental consciousness, such as Canada (4.95) and Australia (4.90), are likely to send travellers with a heightened appreciation and sensitivity to the unique natural environment of Antarctica. This deep-seated appreciation may manifest in profound admiration for the continent's pristine beauty, coupled with an acute awareness of the environmental challenges it faces. Conversely, countries with lower environmental awareness, like China (3.01), may produce travellers with a less focused perspective on the environmental aspects of the journey. This distinction highlights the crucial role of environmental education [55] and awareness in shaping travellers' experiences and perceptions, particularly in regions as ecologically sensitive [17] as Antarctica (Figure 6).

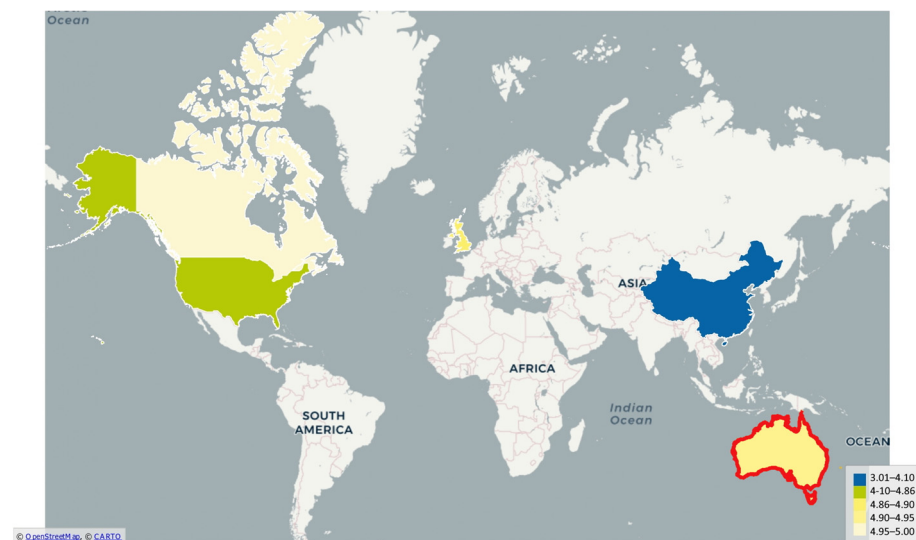


Figure 6. Data mining of the environmental dimension in countries with the highest number of reviews.

This figure presents a world map highlighting the countries with the highest number of travel reviews that represent the environmental dimension. On the map, Australia stands out as the country with the most reviews in this category. The colour scale is defined as follows: blue indicates the lowest frequency of reviews, green tones represent a moderate number, and yellow indicates the highest frequency.

3.4. Temporal Evolution of Sentiments on Visiting Antarctica

We obtained the following results after using the sentiment analysis tool, model, and lexical database (VADER) [34], along with SAT for evaluating lexical and inter-lexical characteristics [37].

The sentiment analysis of travellers to Antarctica from 2012 to 2024 offers a nuanced perspective on the emotional responses to a unique and evolving environmental context (Figure 7). This period is marked by significant global changes, which are critical to understanding the fluctuations in sentiment. A detailed examination reveals the influence of specific events and trends that could have shaped these emotional responses.

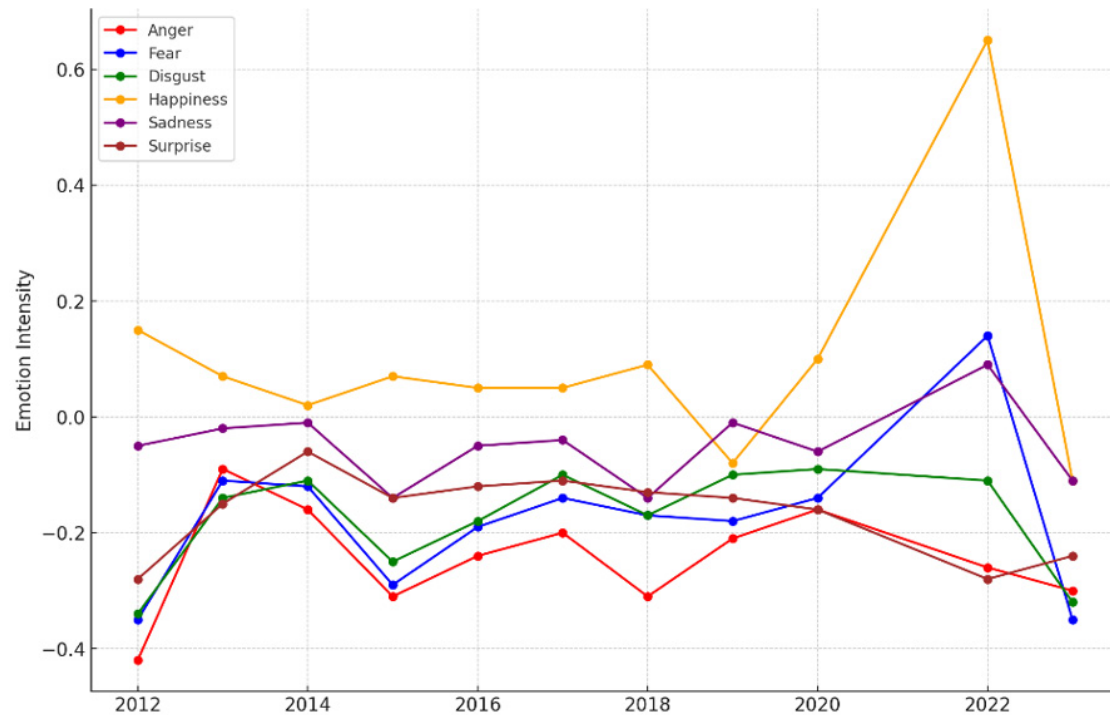


Figure 7. Emotional trends over time.

The sentiment analysis of travellers to Antarctica from 2012 to 2024 reveals a complex emotional landscape [56] significantly influenced by environmental factors, global events, and the evolving nature of Antarctic tourism. This period, encompassing various global and environmental changes, provides a profound insight into the fluctuating emotional responses of travellers.

Anger levels among travellers exhibited a dynamic pattern over the years. Initially, 2012 saw peak negativity, likely due to logistical challenges and unmet expectations in the harsh Antarctic environment. Conversely, 2013 marked a noticeable decrease in anger, reflecting the maturation of the Antarctic tourism industry and enhanced traveller experiences. However, a resurgence of negative sentiment by 2023 could be linked to post-pandemic tourism surges, leading to overcrowding and potentially diminished experiences. Stricter environmental regulations, vital for ecosystem preservation but possibly perceived as restrictive, may have also fuelled this frustration [57].

Concurrently, fear among travellers remained predominantly negative, with significant peaks in 2012 and 2023. The heightened fear in 2012 likely stemmed from increased media focus on climate change's dramatic impacts on the polar regions. The dip in fear in 2022 could be attributed to a boost in confidence from the successful rollout of COVID-19 vaccines, alleviating health concerns in remote travel [58]. However, the return of heightened fear levels in 2023 possibly reflects ongoing concerns about health safety,

emphasising the intricate connection between global events, environmental changes, and travellers' emotions.

The sentiment of disgust remained consistently negative throughout the period, particularly high in 2012 and 2023. This sentiment was likely driven by visible effects of climate change and environmental degradation [59] in Antarctica, such as ice shelf collapses and wildlife habitat disturbances. The stability of this sentiment underscores a sustained concern among travellers about the human impact on Antarctica's pristine environments. In contrast, happiness among travellers showed notable variability, peaking significantly in 2022 before declining in 2023. The spike in 2022 closely aligns with the easing of COVID-19 travel restrictions, offering a renewed opportunity for adventure and exploration [60]. However, the subsequent decline suggests shifting expectations and possibly a diminishing novelty factor in Antarctic travel, influenced by evolving perceptions and environmental concerns.

Sadness exhibited a gradual increase, with significant spikes in 2015, 2018, and 2023. These increases are closely linked to heightened awareness of the Antarctic ecosystem's fragility, influenced by major reports on climate change impacts. The intensified sadness in 2023 might reflect ecological grief in response to visible environmental changes, amplified by the post-pandemic global focus on environmental issues [61].

The sentiment of surprise was consistently negative, indicating that travel experiences often met or fell short of expectations. The slight improvement in 2014 might be attributed to specific positive developments, such as exceptional wildlife sightings or favourable weather conditions, highlighting the authenticity and predictability of the polar travel experience.

Lastly, the anomaly of 2022 stands out, marked by increased happiness and decreased anger and fear. This shift is likely a result of the post-pandemic context, a potentially rejuvenated Antarctic environment following reduced human presence, and possibly advancements in conservation efforts or enhanced tourism practices. This year exemplifies how external factors and regional developments can profoundly influence the emotional responses of travellers to one of the world's most remote destinations [62].

3.5. Sentiment Analysis: Spectrum of Emotions in Journeys to Antarctica

In this study, we examine how the intrinsic characteristics of travellers' cities of origin may influence their perceptions and emotions during a journey to Antarctica. The analysed data suggest that potential factors such as cultural diversity, economic and educational development, connection with nature, and a city's climate and lifestyle might impact the emotional experience of travellers in Antarctica, in line with Holden et al. [63].

Cosmopolitan cities like New York (happiness: 0.02) and London (happiness: 0.12) are characterised by their high cultural diversity and a wide range of experiences (Figure 8). Inhabitants of these cities tend to exhibit more positive reactions towards Antarctica, with lower levels of fear and surprise. This indicates a greater openness and adaptability to new and challenging experiences [64]. Conversely, in cities with a focus on technology and sustainability, such as San Francisco, there is observed emotional preparedness for unique environments, albeit with a more marked sensitivity towards environmental concerns.

In cities with a strong connection to nature and sustainability, such as Seattle (sadness: -0.10), Denver (happiness: 0.19), and Melbourne, more intense emotions towards Antarctica are noted, reflecting a greater sensitivity to the beauty and uniqueness of the natural environment. This manifests in a profound appreciation and, at times, more acute environmental concerns, as seen in Sydney (sadness: -0.33).

Cities with a high level of economic and educational development, such as Boston (disgust: -0.36), tend to show intense emotional reactions, particularly in terms of sadness and disgust. This could be indicative of a heightened awareness of global environmental issues, such as climate change, which intensifies during the Antarctic experience. In contrast, in cities focused on urban growth and warm climates, like Atlanta (happiness: 0.00), the Antarctic experience may be more challenging but manageable.

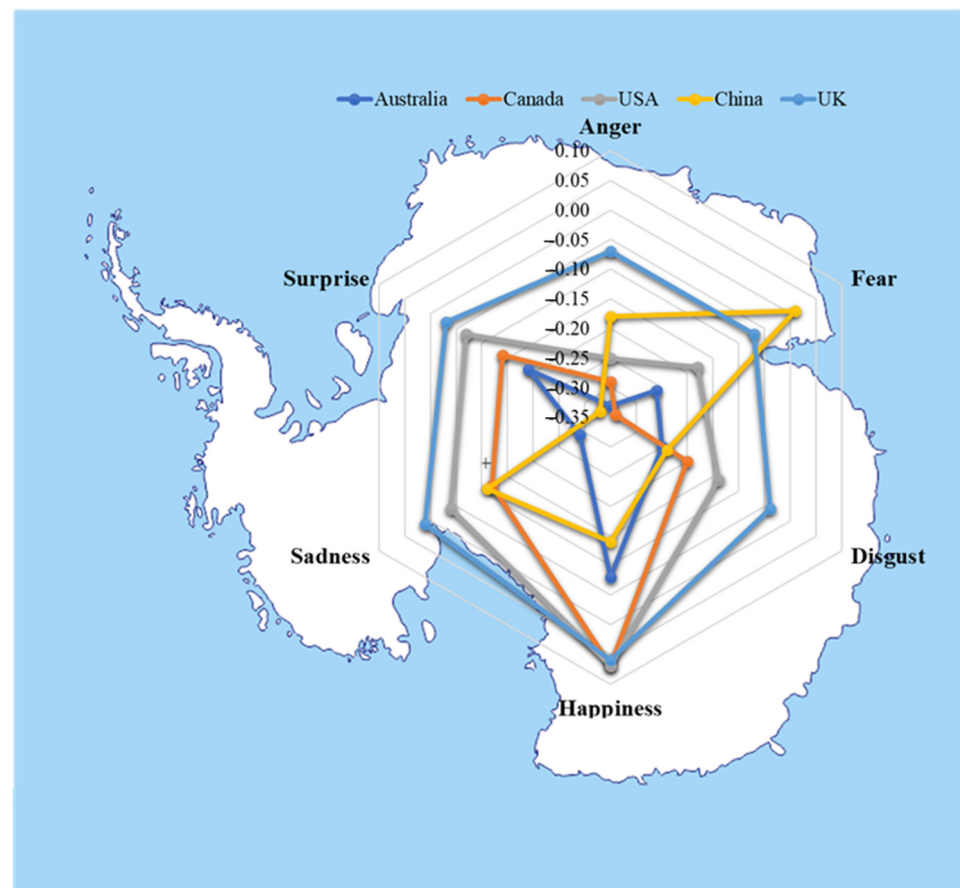


Figure 8. Antarctic geography of feelings.

Variations in anger and fear in cities accustomed to varied or challenging climates, such as Denver (anger: -0.36) and Seattle (anger: -0.25), may reflect the resilience and adaptability of their inhabitants. This suggests greater preparedness to face and adapt to extreme conditions [65], such as those encountered in Antarctica.

Socioeconomic levels and lifestyle in cities like Houston (happiness: -0.01) and Orlando (happiness: 0.23) also play a crucial role in the perception of the Antarctic experience. While in Houston, less focused on outdoor activities, mixed emotions are observed, in Orlando, known for its tourism and entertainment, a more relaxed and positive attitude towards new experiences is noted.

In conclusion, our exploration revealed that cities with a profound connection to nature and sustainability witness intensified emotions, reflecting a deeper appreciation for Antarctica's natural beauty and, at times, heightened environmental concerns. Advanced urban centres exhibit intense emotional reactions, signalling a heightened awareness of global environmental issues during the Antarctic journey.

Moreover, the resilience and adaptability of inhabitants from cities accustomed to challenging climates underscore their preparedness to face extreme conditions encountered in Antarctica. Socioeconomic levels and lifestyle further contribute to the nuanced perception of the Antarctic experience, with cities emphasising tourism and entertainment fostering a more positive and relaxed attitude.

This intricate web of influences underscores the need for a tailored approach in understanding and addressing the diverse emotional responses of travellers to Antarctica. By acknowledging these city-specific dynamics, stakeholders in Antarctic tourism can better tailor their offerings, ensuring a more enriching and sustainable experience for a global audience with varied backgrounds and expectations.

4. Discussion

This study's analysis illuminates critical aspects of Antarctic tourism through topic modelling and sentiment analysis, revealing a nuanced understanding of visitor behaviour and emotional responses within the sustainability framework of Agenda 2030. The interrelation of geographic and temporal factors, alongside the identified behavioural patterns, underscores the complexity and depth of sustainable tourism in this unique landscape [38,39].

The spatial dimension of Antarctic tourism, as highlighted by the topic modelling, reflects a diverse visitor demographic, hinting at the increasing global interest in the continent's tourism. However, this geographical diversity brings to the fore the need for effective international collaboration and governance to safeguard the fragile ecosystems, in line with SDG 17 [38]. The modelling also accentuates the temporal aspect of tourism, where seasonality plays a pivotal role in visitor engagement and experience, suggesting the need for meticulous management of tourism schedules to minimise ecological disturbance [5,39].

Furthermore, our findings indicate a commitment to sustainable practices among tourists, with the adoption of eco-friendly modes of transportation and a discerning approach to packing. Such behaviours are in concert with several SDGs, particularly those related to responsible consumption and Climate Action (SDGs 7, 11, 13, and 14) [40,41]. Notably, the discourse around transportation aligns with the trend towards minimising carbon footprints, whilst the emphasis on equipment and preparation suggests an emergent culture of sustainability-oriented travellers [40,41].

In examining behavioural patterns, a significant alignment with SDGs is observed, reflecting a conscious shift towards eco-friendly tourism practices [18,23,25]. The tour operators' array signals an economic impetus behind Antarctic tourism, with a clear nod towards sustainability goals, thus resonating with the imperatives of SDGs 8 and 9. It becomes evident that fostering sustainable practices and cultivating responsible tourism are critical to inciting transformational outcomes, a sentiment echoed in the literature [42].

The sentiment analysis offers an overview of the emotions associated with Antarctic tourism, revealing a spectrum of feelings influenced by a range of socioeconomic and environmental factors [56,62]. The variation in sentiments, from happiness to fear and disgust, underscores the profound impact of global events and environmental concerns on tourists' experiences [57,61]. Interestingly, the data suggest that the origins of travellers might influence their emotional responses, with cities boasting high levels of cultural diversity, economic and educational development, and environmental consciousness shaping more positive perceptions [63–65].

To better align our research with the objective of benchmarking SDG targets, we have deepened the integration of SDG considerations into our analysis of tourists' emotional responses to Antarctic experiences. This approach provides a nuanced understanding of how these emotions interplay with sustainable development initiatives.

Our findings highlight the dual role of positive and negative emotions in shaping tourist behaviours aligned with specific SDGs. For example, emotions of happiness and awe, sparked by the pristine conditions of Antarctica, can enhance commitment to SDG 13 (Climate Action) and SDG 14 (Life Below Water), motivating tourists towards sustainable actions [66]. In contrast, emotions like fear or sadness, triggered by visible environmental degradation, could drive tourists to support SDG 12 (Responsible Consumption and Production), reflecting a conscious shift towards sustainability in response to observed impacts [67]. Additionally, this study examines how the emotional connections tourists form, influenced by their origin cities' cultural and socioeconomic contexts, can further impact their engagement with the SDGs. This aspect of our analysis provides insights into the potential for targeted educational programs that leverage emotional responses to foster a deeper commitment to sustainable practices [68]. By weaving the SDGs into our emotional analysis, we offer a comprehensive view of the potential for emotions to act as catalysts for sustainable behaviours among tourists in Antarctica. This integration not only aligns with the thematic focus of our study but also enhances its applicability in guiding

effective management practices for sustainable tourism, highlighting the importance of emotional engagement in achieving broader sustainability goals [69,70].

Our discussion reiterates the significance of managing Antarctic tourism's temporal and geographical aspects while fostering sustainable behaviour among tourists. Recognising the importance of city-specific dynamics in influencing tourists' experiences is paramount. It is through such nuanced understanding that the sector can adapt and evolve to meet the ambitious goals of Agenda 2030 [42,62]. As Antarctic tourism continues to grow, stakeholders must navigate the fine balance between visitor engagement and environmental stewardship to ensure the long-term viability of this extraordinary destination [38,39].

Our study provides valuable insights into the factors influencing tourists' perceptions and behaviours in Antarctica, contributing to the advancement of theoretical knowledge in the fields of sustainable tourism, environmental perception, and behaviour geography. By applying the EPBG framework [11] to the context of Antarctic tourism, we have demonstrated the utility of this theoretical approach in understanding the complex interplay between tourists' cultural backgrounds, socioeconomic status, and environmental values in shaping their perceptions and behaviours [10,71]. Our findings support the core tenets of EPBG theory while also highlighting the unique challenges and opportunities presented by the Antarctic tourism context. Furthermore, our research has implications for other relevant theoretical perspectives, such as the theory of planned behaviour [72] and the value-belief-norm theory [71]. By examining how our results align with these theories' predictions about the factors influencing pro-environmental behaviour, we have provided a more nuanced understanding of the psychological and social processes underlying tourists' engagement with sustainability issues in Antarctica. Our findings also have significant practical implications for the development and implementation of sustainable tourism policies and practices in Antarctica. Tourism operators could develop targeted educational programs and interpretive materials that highlight the unique environmental and cultural values of Antarctica, leveraging the emotional impact of tourists' experiences to foster greater awareness and engagement with sustainability issues [3]. Policymakers could use our findings to inform the design of regulations and guidelines that encourage responsible tourist behaviour and minimise the negative impacts of tourism on the fragile Antarctic ecosystem [5].

However, we acknowledge the limitations and existing problems that warrant further investigation, such as the reliance on a single data source and the need for more longitudinal and comparative research. Future research could explore the potential of new technologies and innovative approaches to enhance the sustainability of Antarctic tourism, such as the use of virtual and augmented reality technologies or the development of eco-friendly transportation and accommodation options [31]. Ultimately, our study underscores the importance of developing more sustainable and responsible approaches to tourism in Antarctica, which balance the desire for unique and meaningful visitor experiences with the imperative to protect and conserve this fragile and precious ecosystem for future generations [32].

In the interpretation of the results, this study has acknowledged significant research gaps in the field of Antarctic tourism, particularly concerning sustainable management practices under the SDGs. We have identified a critical need for a deeper understanding of tourist behaviours in Antarctica and their impacts on its fragile ecosystem. While previous studies have highlighted general trends in polar tourism, there remains a lack of detailed analysis on how individual tourist interactions with the environment, wildlife, and cultural heritage sites directly influence ecological and cultural sustainability. This study has explored the alignment of Antarctic tourism practices with the SDGs, identifying areas where tourism either supports or undermines these goals. While there are efforts to align with SDGs such as Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), and Life Below Water (SDG 14), there are still considerable challenges to be addressed. This finding suggests that more robust and integrated management strategies are necessary to harness the full potential of sustainable tourism practices in Antarctica.

5. Conclusions

In conclusion, this study represents a pioneering effort to unravel the intricate landscape of Antarctic tourism through EPBG. By employing both topic modelling and sentiment analysis on Online User-Generated Content, our research not only achieved the intended quantitative analysis but also provided a comprehensive perceptual discourse within the framework of Agenda 2030.

The findings of this study contribute significantly to the understanding of sustainability concerns among current and potential visitors to Antarctica. The identification of these concerns based on User-Generated Content emphasises the importance of online platforms in shaping perceptions and decision-making in the context of a destination as unique and ecologically vulnerable as Antarctica.

Moreover, the sentiment analysis offers a nuanced view of sustainability within the perceptual landscape of travellers. By exploring dimensions of economic, social, and environmental sustainability, as well as various emotional geographies, our study provides a rich tapestry of insights into the multifaceted nature of Antarctic tourism experiences.

Theoretical contributions extend to the realm of perception geography, presenting a replicable methodology applicable in diverse contexts. Empirically, this research stands as a testament to the potential vulnerabilities and challenges faced by Antarctica as a tourism destination, necessitating a delicate balance between exploration and preservation.

Our study presents a detailed analysis of the emotional dimensions of Antarctic tourism, focusing on their connection to sustainability outcomes, particularly through the lens of EPBG and theories like the theory of planned behaviour and value-belief-norm (VBN). We found that tourists' emotional responses vary with their cultural and socioeconomic backgrounds, influencing their sustainability-oriented behaviours [10,11]. Furthermore, we draw parallels between our findings and prior research, emphasising how emotional responses to the Antarctic environment can foster support for Sustainable Development Goals (SDGs), such as SDG 13 (Climate Action) and SDG 14 (Life Below Water) [71,72]. Our analysis also benefits from insights gained from recent studies which explore the role of emotions in promoting environmentally responsible behaviours [73] and the application of the VBN theory in different geographical contexts [17,74]. Our contribution extends the dialogue on sustainable tourism by exploring the emotional impacts of tourism in polar regions and their implications for sustainable practices, building on findings from Bastmeijer and Lamers [32] and Liggett et al. [5]. By employing advanced sentiment analysis techniques, we further advance methodological practices in tourism research, echoing the innovative approaches discussed in recent studies [33].

This enriched discussion not only deepens the theoretical grounding of our study but also offers practical insights for developing sustainable tourism policies in Antarctica, highlighting the need for strategies that consider the diverse cultural backgrounds of tourists. Our findings suggest that emotional engagement with the environment is a critical factor in promoting sustainable behaviours, a theme that is increasingly relevant in the discourse on global sustainability efforts [73–75].

However, acknowledging the limitations inherent in our approach is crucial for a comprehensive interpretation of the results. Cultural and psychological factors, varying levels of preparedness, and the influence of climate change awareness contribute to the complexity of travellers' sentiments. While these limitations underscore the need for further research, they also illuminate potential avenues for future investigations to enhance the understanding of the evolving relationship between travellers, Antarctica, and sustainability considerations. In essence, this scholarly paper lays the foundation for continued exploration and discourse on the sustainability dynamics within the unique context of Antarctic tourism.

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preparation, V.C.-F., M.P.-C., and I.R.-R.; writing—review and editing, V.C.-F., M.P.-C., and I.R.-R.; visualisation, V.C.-F. and M.P.-C.; supervision, I.R.-R.; funding acquisition, M.P.-C. All authors have read and agreed to the published version of the manuscript.

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