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Utilizing Topic Modeling to Identify Sustainability Trends in the Golf Industry

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Abstract: The environmental impact of the golf industry has garnered increasing attention, emphasizing the need for sustainable practices in golf course management. This study aims to develop strategic frameworks that enable the golf industry to address global environmental challenges and integrate eco-friendly principles. Utilizing topic modeling, the research examines key areas such as pesticide use, waste management, and energy consumption within golf courses, and explores strategies for achieving carbon neutrality and developing sustainable golf wear and branding. The findings reveal specific management practices that significantly reduce environmental harm, including integrated pest management, waste reduction techniques, and the adoption of renewable energy sources. Case studies of leading golf clubs demonstrate successful implementation of carbon neutrality strategies. Furthermore, the research highlights the potential of eco-friendly golf wear to enhance brand credibility and meet consumer demands. These insights hold valuable implications for golf course managers, club operators, policymakers, and golfers, promoting a comprehensive approach to sustainability in the golf industry. The study's contributions extend beyond the immediate environmental challenges, offering a framework for long-term sustainability and competitive advantage.

Keywords: topic modeling; LDA; sustainability; eco-friendly practices; golf industry

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1. Introduction

The golf industry, known for its extensive landscapes and aesthetic appeal, plays a significant role in sports tourism and recreational activities worldwide [1,2]. However, its environmental impact has become a critical concern in recent years [3]. Studies have increasingly focused on the sustainability practices within the golf industry, examining areas such as water usage, pesticide application, and land management [4–6]. Guzmán et al. [7] highlighted the significant environmental footprint of golf courses, noting that water consumption and chemical use are particularly concerning. Similarly, research has emphasized the necessity for eco-friendly practices in golf course management, suggesting that sustainable operations could mitigate adverse environmental effects [8,9]. Despite these insights, the implementation of comprehensive, eco-friendly strategies in the golf industry remains inconsistent and often lacks a systematic approach.

While the existing literature provides a foundation for understanding the environmental challenges of golf course management [10,11], there are notable gaps and unexplored areas. Specifically, detailed analyses of the specific management practices that can mitigate environmental impacts, such as the application of pesticides and waste management, are scarce. Babb-Hartman [12] and Tsai [13] discussed the general risks associated with pesticide use but did not offer specific management strategies tailored to different golf course components. Additionally, there is limited research on the practical implementation of carbon neutrality within the golf industry. While Agoro et al. [14] discussed the importance of reducing carbon emissions, comprehensive strategies for achieving carbon neutrality in

golf course operations are not well-documented. Furthermore, the potential of sustainable golf wear and eco-friendly branding to enhance environmental stewardship in the golf sector has not been thoroughly investigated.

Investigating these gaps is crucial for several reasons. The environmental impact of golf courses, including water pollution from pesticide runoff and the carbon footprint of course maintenance, poses significant risks to local ecosystems and communities [15,16]. As the global community increasingly prioritizes sustainability, the golf industry must adopt more eco-friendly practices to align with broader environmental goals and maintain its social license to operate [3,6]. Failure to address these issues could lead to stricter regulations, increased operational costs, and a decline in public support for golf activities. Additionally, with consumers becoming more environmentally conscious, the demand for sustainable products and practices is rising [17–19]. Golf clubs and brands that fail to meet these expectations may find themselves at a competitive disadvantage.

This study proposes a comprehensive analysis of strategic and sustainable practices within the golf industry, utilizing topic modeling to identify key areas for action. By examining the specific environmental impacts of golf course operations, such as pesticide use and waste management, this research aims to provide actionable insights for managers and policymakers. The study also explores strategies for achieving carbon neutrality in golf courses, offering practical examples from leading golf clubs. Additionally, the research investigates the development of eco-friendly golf wear and branding, highlighting the potential benefits of sustainable products in enhancing brand credibility and consumer perception. This approach not only addresses the immediate environmental challenges but also provides a framework for long-term sustainability in the golf industry.

Our study employs a comprehensive methodology to analyze the sustainability practices within the golf industry. We use Latent Dirichlet Allocation (LDA), a probabilistic graphical model for topic modeling, to identify and analyze key themes and trends within a large dataset of news articles [20]. Additionally, we utilize word cloud visualization to present the most frequently occurring terms in an intuitive manner, enabling quick identification of prominent themes [21]. The data was processed using Python 3.0, employing the Kkma morpheme analyzer 2.0 to extract relevant nouns and eliminate stopwords. This combination of methodologies, including the use of perplexity and coherence scores to evaluate the LDA model, provides a robust framework for understanding the current state of eco-friendly practices in the golf industry.

The contributions of this study are multifaceted. Firstly, it bridges the gap in the literature by providing detailed analyses and practical solutions for the environmental management of golf courses. The insights into pesticide management and waste reduction are particularly valuable, offering golf course managers clear guidelines for minimizing environmental harm. Secondly, the study advances the theoretical framework on carbon neutrality in the golf industry, presenting concrete strategies and case studies that other clubs can replicate. This extends the existing literature by providing a detailed roadmap for achieving carbon neutrality. Thirdly, the research sheds light on the underexplored area of sustainable golf wear and branding, demonstrating how eco-friendly products can enhance brand competitiveness and meet consumer demands. Finally, the study offers valuable implications for policymakers, suggesting supportive frameworks and regulations that can promote sustainable practices in the golf industry.

In summary, this research provides a comprehensive and actionable framework for enhancing environmental sustainability in the golf industry. By addressing gaps in the literature and offering practical solutions, it contributes significantly to the field of sports sustainability, helping to align the golf industry with global environmental goals.

2. Materials and Methods

2.1. Research Materials

Our aim was to rapidly capture social phenomena. Unlike academic papers, which undergo a lengthy process of observation, analysis, writing, and peer review before publi-

cation, news articles are disseminated quickly, providing timely information to the public. This study focuses on articles from the three most recent years (2021–2023) to ensure relevance and immediacy. This timeframe was chosen to reflect current trends and practices in the golf industry's sustainability efforts. To fulfill the objectives of this research, news articles sourced from Google (www.google.co.kr, accessed on 11 April 2024) and Naver (www.naver.com, accessed on 11 April 2024) were selected as research materials, based on searches conducted using the keywords "golf eco-friendly" and "golf ESG".

The search was comprehensive, covering all available pages up to the most recent. Out of the initially gathered articles, 81 from Google and 442 from Naver, duplicates and irrelevant articles were removed, resulting in a final dataset of 379 articles for analysis. We selected Naver and Google as primary data sources due to their extensive coverage and authoritative nature. Naver, being the predominant portal in South Korea, publishes nearly all local news, providing essential, context-specific insights. Google was used in a supplementary context to capture any articles that might have been missed by Naver, ensuring a comprehensive dataset that combines both local and international perspectives.

2.2. Research Tools

2.2.1. Word Cloud Visualization Analysis

Word cloud visualization analysis is a technique that visually represents words based on their frequency, allowing for the rapid identification of prominent terms [21]. In word cloud visualization, the size of each word is directly proportional to its frequency of occurrence within the dataset, enabling immediate visual recognition of the most salient themes. Colors are strategically assigned to enhance visual appeal and categorize words into thematic groups.

Compared to other bibliometric tools like VOSviewer 1.6.19 and Citespace 6.1.5, word cloud visualization offers unique advantages and limitations. VOSviewer excels in detailed network visualizations and identifying relationships between terms, authors, or publications [22]. Citespace is a powerful tool used for detecting trends and critical paths in literature [23]. However, these tools can be complex and have steep learning curves. Word cloud visualization, in contrast, provides simplicity and accessibility, allowing for immediate interpretation of key themes. Its straightforward approach makes it effective for exploratory data analysis and quick overviews of large text datasets. This study selected word cloud visualization to present frequently occurring terms intuitively, complementing more detailed analyses in other sections.

2.2.2. Topic Modeling

Topic modeling analysis, a method used to extract topics from a large corpus of text and ascertain the thematic composition of each document, facilitates understanding of the text's meaning and yields insights into specific topics [24].

2.2.3. LDA

To enhance our analysis, we employed the LDA model. The perplexity score evaluates the quality of the topic model created by the LDA model, with a lower perplexity score indicating the model's higher probability of accurately predicting new documents. Conversely, the coherence score assesses how semantically consistent and connected the topics extracted by the LDA model are, with a higher coherence score suggesting greater semantic consistency among topics [25]. These metrics help ensure the reliability and validity of our topic modeling results.

2.3. Data Processing Methods

This research conducted text analysis using Python 3, emphasizing the importance of text preprocessing for enhancing the accuracy of textual data analysis. By utilizing the Kkma morpheme analyzer, morphemes were categorized as NNG (general nouns) and NNP (proper nouns), and only nouns consisting of two or more characters were extracted.

The Kkma morphological analyzer is a tool for analyzing the morphology of Korean text, helping to identify and parse words and grammatical structures within sentences. After eliminating stopwords and unnecessary words, words frequently used in sequence were transformed into compound nouns for processing. Words deemed irrelevant to the topic, such as "Incheon", "Chungbuk", "Seo-gu", "Haejin", "Shinsegae", "X", and "leading", were also removed. The extracted words were then translated into English for the word cloud visualization analysis, and the top 100 words from the entire text were displayed. The number of topics was limited to between two and eight, considering perplexity and coherence scores, and documents were categorized into topics using the LDA method. PyLDAvis was employed for visual representation of the words associated with each topic. Finally, the textual material was analyzed and interpreted through frequency and topic modeling. PyLDAvis is a Python library designed to help interpret and visualize the topics in a topic model generated using LDA. The resultant words were ultimately translated into English.

3. Results

3.1. Frequency Extraction Analysis

Upon analyzing the frequencies within the selected research materials, a closer look at the main keywords reveals the inclusion of terms such as Eco-friendly (205), Golf Course (182), Pesticide (44), Golfwear (34), Management (24), Park (20), Club (18), among others, as shown in Table 1.

Table 1. Frequency extraction (top 20 cases).

Number	Word	Frequency
1	Eco-friendly	205
2	Golf Course	182
3	Pesticide	44
4	Golfwear	34
5	Management	24
6	Park	20
7	Club	18
8	Course	17
9	Operation	16
10	Supplies	16
11	Tournament	15
12	Trash	13
13	Landfill	13
14	Brand	12
15	Residue	12
16	Dream	12
17	Usage	11
18	Finance	11
19	Region	11
20	Activity	11

3.2. Word Cloud Visualization Analysis

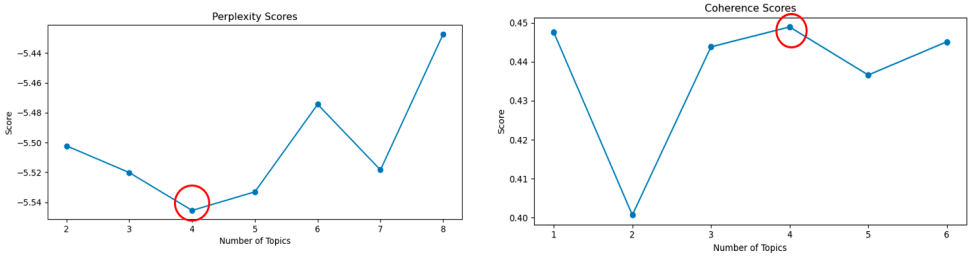
Word cloud visualization analysis involves the visual identification of keywords within documents or textual data. In this study, based on the extracted frequency values, a word cloud visualization analysis was conducted for 100 words, as shown in Figure 1.

Figure 1. Word cloud visualization analysis.

The results displayed the words in sizes proportional to their frequency. Upon closer inspection, aside from the main keywords such as Eco-friendly, Golf Course, Golfwear, Pesticide, and Supplies, other keywords that emerged include Carbon neutral, Brand, Energy, Safety, and Coexistence.

3.3. Selection of the Number of Topics

After applying the LDA (Latent Dirichlet Allocation) technique, Perplexity and Coherence scores were derived, leading to the selection of an appropriate number of topics, as shown in Figure 2.



Visualization of Perplexity Scores Visualization of Coherence Scores

Figure 2. Selection of the number of topics using the LDA technique.

Upon examining the Perplexity and Coherence scores for the selection of the number of topics for the data, Perplexity showed a low level at four points, and Coherence peaked at four points, leading to the selection of four topics as the appropriate number. The Perplexity score is one of the metrics used in the field of natural language processing to measure the performance of a language model [26]. It indicates how ambiguously a given sentence is understood, with a lower Perplexity score suggesting that the model performs more accurate predictions. The Coherence score, an important indicator in topic modeling, assesses the quality of the extracted topics. This score typically ranges between 0 and 1, with higher values indicating that the extracted topics are consistent [27].

3.4. Analysis of Topic Selection through pyLDAvis Visualization and Probability Distribution

3.4.1. pyLDAvis Visualization Analysis

The pyLDAvis visualization analysis employed in this research effectively segregated the environmental sustainability topics within the golf industry into four principal categories, as shown in Figures 3–6. The visualization highlights the most significant topic, which pertains to eco-friendly golf course design, commanding 32.6% of the thematic distribution. In contrast, the topic with the least emphasis, involving eco-friendly club activities and community building, accounts for 20.3%. Saliency measures the informativeness of a term across topics by considering both its frequency and distribution [28]. Relevance ranks terms by importance to a topic, balancing term frequency within the topic and overall frequency [29]. This analytical approach not only quantifies the relative importance of each topic but also unveils the interconnected nature of these areas, indicating the necessity of a holistic strategy for fostering an environmentally sustainable golf industry.

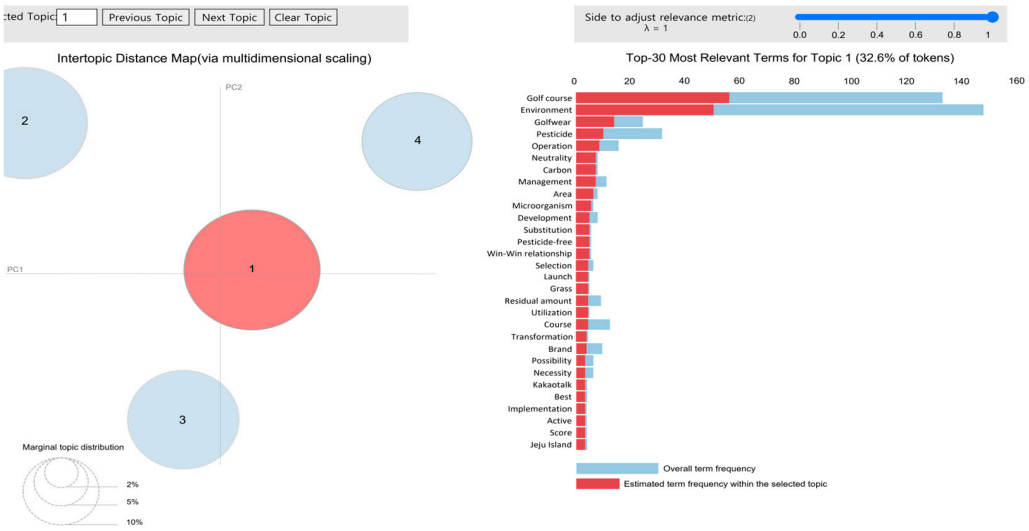


Figure 3. pyLDAvis visualization analysis for Topic 1.

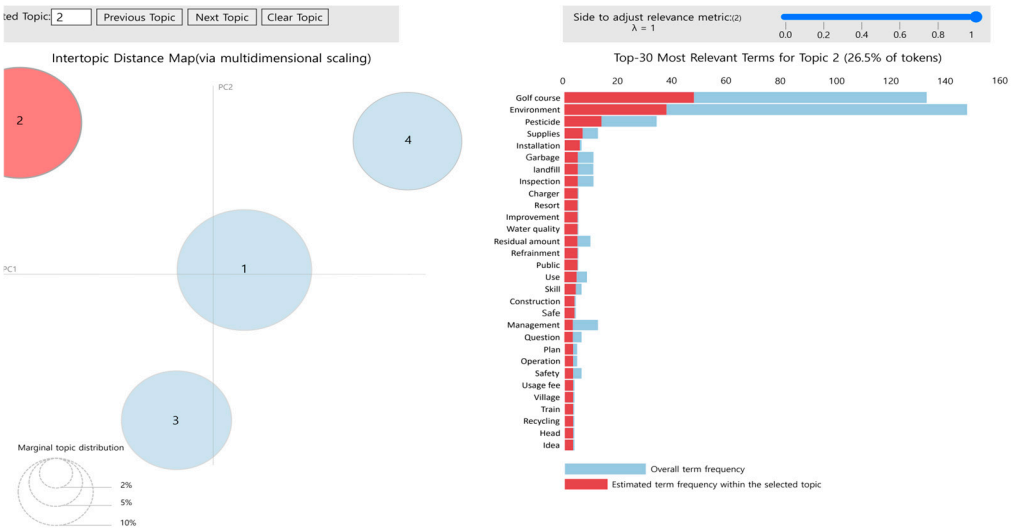


Figure 4. pyLDAvis visualization analysis for Topic 2.

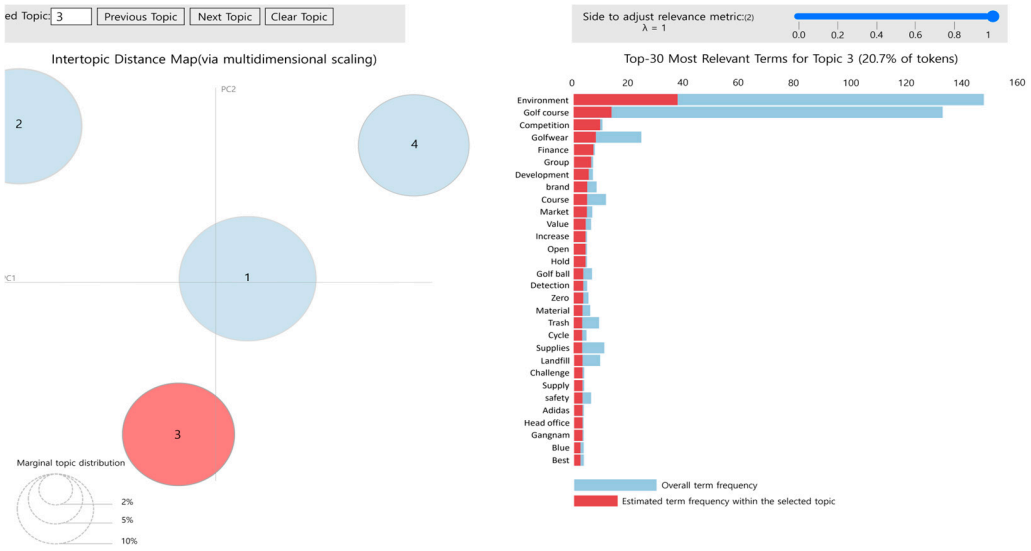


Figure 5. pyLDAvis visualization analysis for Topic 3.

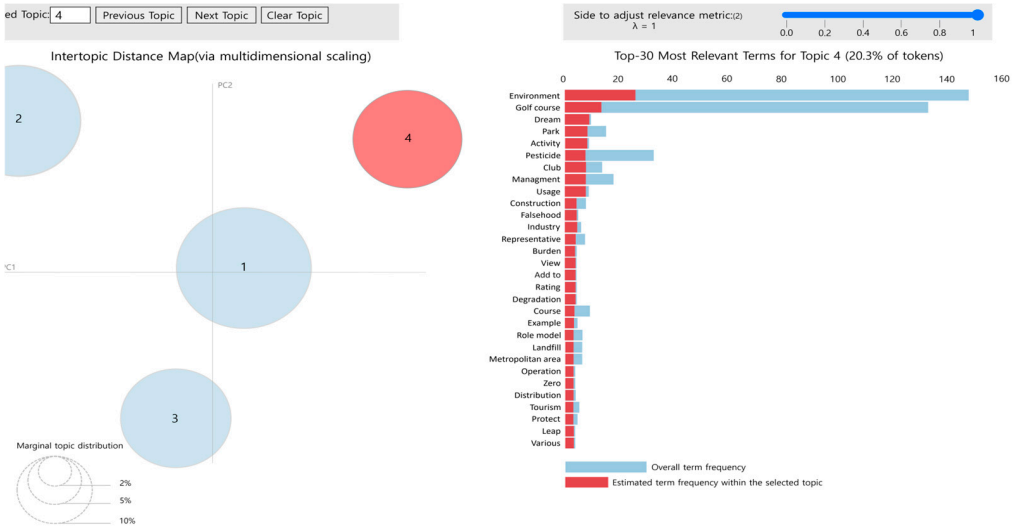


Figure 6. pyLDAvis visualization analysis for Topic 4.

3.4.2. Probability Distribution of Topic Modeling Algorithms

The probability distribution of the topic modeling algorithm is organized by the main words of each topic in order of their weight, as shown in Table 2. For the first topic, the keywords composing the topic are 'Golf Course (0.088)', 'Environment (0.083)', 'Golf Wear (0.040)', 'Pesticide (0.023)', 'Operation (0.020)', 'Neutrality (0.017)', 'Carbon (0.015)', and 'Management (0.015)'. Upon reviewing the original texts of each keyword, the focus was found to be on exploring methods to mitigate environmental impacts (such as pesticide use, waste management, and landfill management) arising from the installation and operation of golf courses. Hence, the topic was named 'Eco-friendly Design and Implementation of Golf Courses'. The second topic's keywords include 'Golf Course (0.072)', 'Environment (0.059)', 'Pesticide (0.051)', 'Supplies (0.030)', 'Installation (0.019)', 'Garbage (0.013)', 'Landfill (0.010)', and 'Inspection (0.010)'. An examination of the original texts for these keywords revealed a focus on strategies to minimize carbon emissions and achieve carbon neutrality in golf course operations. Therefore, the topic was named 'Strategies for Achieving Carbon Neutral Goals in Golf Courses'. The third topic's keywords are 'Environment (0.082)', 'Golf Course (0.067)', 'Competition (0.057)', 'Golf Wear (0.027)', 'Finance (0.016)', 'Group (0.014)', 'Development (0.014)', and 'Brand (0.013)'. The analysis of these keywords emphasized the exploration of eco-friendly manufacturing processes

for golf apparel and accessories and strategies for enhancing brand value through these means. Thus, the topic was named 'Development of Eco-friendly Golf Wear and Brands'. The keywords making up the fourth topic are 'Environment (0.109)', 'Golf Course (0.094)', 'Dream (0.039)', 'Park (0.018)', 'Activity (0.017)', 'Pesticide (0.017)', 'Club (0.016)', and 'Management (0.016)'. Reviewing the texts associated with these keywords highlighted the importance of eco-friendly club activities in golf courses and their positive impacts on the community and environment. Consequently, the topic was named 'Eco-friendly Club Activities and Community Building.

Table 2. Probability Distribution of Topic Modeling Algorithms.

Num.	Topic 1 (32.6%)	Topic 2 (26.5%)	Topic 3 (20.7%)	Topic 4 (20.3%)
	Eco-Friendly Golf Course Design and Implementation	**Strategies for Achieving Carbon Neutrality in Golf Courses**	**Development of Eco-Friendly Golf Wear and Brands**	**Establishment of Eco-Friendly Club Activities and Communities**
1	Golf Course (0.072)	Golf Course (0.088)	Environment (0.082)	Environment (0.109)
2	Environment (0.059)	Environment (0.083)	Golf Course (0.067)	Golf Course (0.094)
3	Golf Wear (0.040)	Pesticide (0.051)	Competition (0.057)	Dream (0.039)
4	Pesticide (0.023)	Supplies (0.030)	Golf Wear (0.027)	Park (0.018)
5	Operation (0.020)	Installation (0.019)	Finance (0.016)	Activity (0.017)
6	Neutrality (0.017)	Garbage (0.013)	Group (0.014)	Pesticide (0.017)
7	Carbon (0.015)	Landfill (0.010)	Development (0.014)	Club (0.016)
8	Management (0.015)	Inspection (0.010)	Brand (0.013)	Management (0.016)

4. Discussion

The purpose of this study is to develop strategic management frameworks that enable the golf industry to effectively address global environmental challenges and integrate eco-friendly principles within its operations. This research utilizes topic modeling to conduct a comprehensive analysis of strategic and sustainable practices within the golf industry, subsequently presenting strategies for its transition towards eco-friendly and sustainable operations. The analysis identified four crucial areas for strategic action.

Firstly, regarding the eco-friendly design and implementation of golf courses, it has been elucidated through this research that analyzing the environmental impacts from the establishment and operation of golf courses and seeking eco-friendly improvement measures are significant undertakings. Key environmental issues in golf course management include the use of pesticides, waste disposal, and landfill management, all of which directly influence the sustainability of golf courses. Notably, the application of pesticides on golf courses is a salient topic. Pesticides are predominantly used for insect and weed control, as well as disease management, and are intrinsically linked to the aesthetic quality of the courses [30]. However, pesticide use has adverse environmental effects, particularly as a principal cause of water pollution. Research indicates differential pesticide risk levels across various golf course components (greens, tees, fairways, etc.), with risks varying according to local pesticide usage and management [12,13]. Further investigation has focused on strategies to mitigate risks associated with pesticide use, particularly in the northern United States, proposing safer pesticide product selection and management strategies [31]. Waste disposal and landfill management in golf course operations also emerged as significant environmental issues. These issues can directly impact the local community and environment, leading to water and soil pollution if not properly managed. Minimizing the energy consumption of clubhouses and golf carts, which are major energy consumers, is also critical [14]. The urgency of adopting high-efficiency lighting, solar panels, and geothermal heating and cooling systems is emphasized. Studies presenting environmental impact minimization strategies have addressed the effects of water usage, chemical

pesticide application, and the introduction of non-native plants, underscoring the need for standardized recommendations for the eco-friendly management and design of golf courses [7]. These findings suggest that eco-friendly design and implementation strategies should be integral components of sustainable environmental management, necessitating exploration of ways in which the golf industry can harmonize with local ecosystems and make positive contributions.

Secondly, achieving carbon neutrality in golf courses is highlighted as a critical issue for environmental protection and sustainable management. Strategies involve minimizing carbon emissions in all aspects of golf course operations and balancing the inevitable emissions through carbon offsetting. Sentosa Golf Club in Singapore, the world's first to practice carbon neutrality, recorded 5000 tons of carbon emissions and achieved neutrality through carbon credits and operations that reduce carbon [32,33]. Since hosting the LPGA Tour HSBC Women's World Championship from 2013, the club has collected $1 per round from members to purchase carbon credits from national parks in Indonesia and Peru, striving to construct an eco-friendly golf course. The Finnish golf association Meri-Teijo Golf in Salo plans to become climate-neutral within five years by utilizing carbon offsets in accordance with the UN's Climate Neutral Now initiative. The initiative emphasizes reducing carbon footprints, utilizing clean and renewable energy, and offsetting non-reducible emissions. The association has switched to wind energy and is implementing solutions to eliminate food waste, another greenhouse gas source. These strategies and measures are crucial for achieving carbon neutrality and building a sustainable golf industry, contributing to environmental protection, operational efficiency, and long-term sustainability. Efforts by global corporations to achieve carbon neutrality in golf courses are expected to expand, setting new sustainability standards across the sports industry.

Thirdly, the development of eco-friendly golf wear and brands plays a key role in the sustainable evolution of the golf industry. Utilizing high-quality organic cotton in golf wear production and employing recycled ocean plastic and polyester or nylon derived from fishing nets are part of these efforts. Over 80% of products should be made from sustainable materials, with minimal water and electricity use [34]. Sustainable management and productization processes address gaps in sustainability trends within the textile, apparel, and fashion industries, shedding light on the environmental impact of clothing manufacture and transportation, greenhouse gas emissions, and the exploitation of cheap labor in developing countries [35,36]. Eco-friendly golf wear and brands can establish a differentiated image in the market as consumers become more environmentally conscious, enhancing brand credibility and providing a positive image. This is crucial for constructing a sustainable golf culture and significantly enhancing brand competitiveness.

Fourthly, eco-friendly club activities and community building play a pivotal role in the sustainable development of golf course operations. Transitioning golf courses to eco-friendly practices by enhancing biodiversity, limiting pesticide use, sourcing local foods, reducing water consumption, and improving waste management fosters a positive relationship with the natural environment, contributing to wildlife protection, biodiversity enhancement, and climate change mitigation [4]. Sustainable management provides tangible benefits to the local environment and effectively responds to climate change, resource constraints, and regulations. Eco-friendly golf courses attract tourists and provide employment opportunities, especially in regions where golf tourism is prevalent, attracting environmentally conscious travelers [37,38]. Educating golfers and the community as to environmental protection raises awareness about sustainable management practices and resource conservation, strengthening overall environmental conservation consciousness [39]. Golf courses offer employment opportunities and attract tourists, particularly in regions with developed golf tourism [40].

Eco-friendly club activities and community building are integral to golf course operations, demonstrating that golf courses can evolve to be environmentally sustainable and positively impact the local community. These efforts present new directions for sustainable

development across industries, emphasizing a responsible approach to community and environmental stewardship.

5. Implications and Limitations

5.1. Theoretical Implications

This study offers substantial theoretical contributions to the discourse on integrating eco-friendly practices within the golf industry. By employing topic modeling to analyze the sector's strategic and sustainable practices, this research identifies previously unexplored avenues for eco-friendly and sustainable golf operations.

Firstly, while prior research has acknowledged the environmental impact of golf courses, few studies have systematically dissected the specific areas of pesticide use, waste disposal, and energy consumption within golf courses. For instance, previous research by Guzmán et al. [7] discussed general environmental impacts but did not delve into specific management practices. This study goes further by detailing the environmental challenges and proposing actionable strategies for pesticide management, waste reduction, and energy efficiency. The application of pesticides, identified as a significant source of environmental degradation, is examined in-depth, highlighting risks and management strategies not fully explored in previous studies [13,30]. This research thus bridges a critical gap by providing detailed insights and practical solutions for mitigating these impacts, thereby enhancing our understanding of sustainable golf course management.

Secondly, this research advances the theoretical framework on carbon neutrality in the golf industry. Previous studies, such as those by Agoro et al. [14], have emphasized the importance of reducing carbon emissions but lacked a comprehensive strategy for achieving carbon neutrality. This study not only underscores the significance of carbon neutrality but also offers concrete strategies, such as the use of carbon credits and renewable energy, as supported by case studies of Sentosa Golf Club and Meri-Teijo Golf [32,33]. These findings extend the existing literature by providing a detailed roadmap for golf courses to follow to achieve carbon neutrality. Scholars are encouraged to build on this framework, exploring how these strategies can be adapted to different contexts and scales within the sports industry.

Lastly, the study provides a fresh perspective on the development of eco-friendly golf wear and the role of sustainable branding. While the environmental impact of apparel production has been recognized in broader sustainability discussions, specific attention to golf apparel has been limited. Studies like those by Abbate et al. [35] and Wu et al. [36] have highlighted the general impacts of textile manufacturing but did not focus on sports-specific apparel. This research fills that gap by investigating the use of sustainable materials in golf wear and its implications for brand differentiation and consumer perception. The findings suggest that integrating eco-friendly materials not only reduces environmental impact but also enhances brand credibility and competitiveness. Scholars should consider the implications of sustainable branding in sports apparel, exploring how consumer behavior shifts with increased environmental awareness.

In summary, this study significantly enriches the theoretical landscape by addressing gaps left by previous research. It offers detailed analyses and strategies for sustainable golf course management, carbon neutrality, and eco-friendly apparel development, providing a comprehensive framework for future research in the field of sports sustainability. These contributions underscore the necessity for ongoing scholarly inquiry into practical, scalable solutions for environmental sustainability across various sports sectors.

5.2. Practical Implications

This study holds substantial practical implications for various stakeholders in the golf industry, including golf course managers, club operators, policymakers, and golfers. By examining eco-friendly practices and sustainable strategies, this research offers actionable insights which can be used to enhance environmental stewardship in the golf sector.

Firstly, golf course managers can utilize the findings to implement more sustainable management practices. The detailed analysis of pesticide use and its environmental impacts suggests the need for adopting safer pesticide products and alternative pest control methods. Managers could introduce integrated pest management (IPM) techniques which minimize chemical use while maintaining course quality [41,42]. Additionally, waste disposal and energy efficiency are critical areas where practical changes can yield significant environmental benefits. Installing high-efficiency lighting, solar panels, and geothermal systems can reduce the carbon footprint of clubhouses and golf carts [14]. Managers should consider these upgrades not only for their environmental benefits but also for potential cost savings in the long run.

Golf club operators also stand to benefit from the study's insights on carbon neutrality. The strategies highlighted, such as purchasing carbon credits and using renewable energy sources, can serve as a blueprint for other clubs aiming to achieve similar goals. The case of Sentosa Golf Club, which achieved carbon neutrality through these methods, provides a concrete example for others to follow [43]. Operators can replicate such initiatives by starting small, perhaps by offsetting emissions from specific events or facilities, before scaling up to achieve full carbon neutrality. Additionally, partnering with environmental organizations to purchase carbon credits can further enhance a club's reputation and attract environmentally conscious members and visitors.

For policymakers, the study underscores the importance of creating supportive frameworks and regulations that promote sustainable practices in the golf industry. Policies that incentivize the adoption of renewable energy and sustainable waste management practices can accelerate the industry's transition to eco-friendly operations. For instance, offering tax breaks or subsidies for golf clubs that install solar panels or other green technologies could encourage wider adoption. Policymakers should also consider developing guidelines for pesticide use that prioritize environmental health while allowing for effective pest control [44,45]. Such policies would not only benefit the golf industry but also contribute to broader environmental goals. In addition to the existing strategies, integrating eco-friendly design and implementation in golf courses necessitates exploring ways to harmonize with local ecosystems. This approach aligns with findings from studies on environmental risks and pollution sources, emphasizing the importance of mitigating persistent pollutants and polycyclic aromatic hydrocarbons (PAHs) [46,47]. Sustainable practices should address pollutant management, similarly to strategies used in urban environments to reduce PAH exposure and enhance eco-health [48]. By adopting such comprehensive approaches, the golf industry can significantly contribute to environmental sustainability and public health.

Golfers themselves can play a significant role in driving sustainable practices. By choosing to patronize eco-friendly golf courses and supporting clubs that commit to environmental stewardship, golfers can influence industry standards. Educating golfers about the benefits of eco-friendly practices, such as reduced pesticide use and energy-efficient facilities, can foster a culture of sustainability within the community. Furthermore, golfers can advocate for more sustainable practices by voicing their preferences to club operators and participating in sustainability initiatives organized by their clubs. Such grassroots support is crucial for the long-term success of sustainable strategies in the golf industry. Eco-friendly club activities and community building are integral to golf course operations, demonstrating that golf courses can evolve to be environmentally sustainable and positively impact the local community. These efforts present new directions for sustainable development across industries, emphasizing a responsible approach to community and environmental stewardship.

In conclusion, the practical implications of this study are far-reaching, providing actionable strategies for various stakeholders which can be used to enhance sustainability in the golf industry. By adopting the recommended practices, golf course managers, club operators, policymakers, and golfers can collectively contribute to a more sustainable future for the sport. These efforts not only protect the environment but also ensure the long-term viability and appeal of golf as a responsible and forward-thinking industry. Table 3

summarizes the main managerial recommendations from the study results, providing actionable strategies for golf course managers. These recommendations focus on pesticide management, waste disposal, energy efficiency, carbon neutrality, eco-friendly golf wear, community engagement, policy development, and education and advocacy.

Table 3. Recommendations.

Area of Focus	Recommendation
Pesticide Management	Adopt integrated pest management (IPM) techniques to minimize chemical use while maintaining course quality.
Waste Disposal	Implement comprehensive waste reduction strategies, including recycling and proper landfill management.
Energy Efficiency	Install high-efficiency lighting, solar panels, and geothermal heating and cooling systems.
Carbon Neutrality	Purchase carbon credits and use renewable energy sources to achieve carbon neutrality.
Eco-Friendly Golf Wear	Utilize sustainable materials such as organic cotton and recycled plastics in golf apparel production.
Community Engagement	Foster eco-friendly club activities and community building to enhance local biodiversity and environmental stewardship.
Policy Development	Develop supportive frameworks and regulations to promote sustainable practices in the golf industry.
Education and Advocacy	Educate golfers as to eco-friendly practices and encourage their participation in sustainability initiatives.

6. Conclusions

This study provides significant theoretical and practical contributions to the integration of eco-friendly practices within the golf industry. Through detailed analyses and the use of topic modeling, we identified key areas for sustainable golf course management, including pesticide use, waste disposal, and energy consumption. The study also advances the framework for achieving carbon neutrality and highlights the role of eco-friendly golf wear and sustainable branding. Practical implications for golf course managers, club operators, policymakers, and golfers include adopting integrated pest management, investing in renewable energy, and promoting environmental stewardship. These strategies not only address immediate environmental challenges but also ensure the long-term viability and appeal of the golf industry as a responsible and sustainable sector.

This study is geographically limited to golf courses, utilizing data sourced exclusively from domestic online platforms. To develop a more diversified and comprehensive understanding of eco-friendly practices in varied environmental conditions, the incorporation of global perspectives and methodologies is recommended. While the current research furnishes an extensive outlook, further investigations could benefit from including diverse climatic and geographical landscapes to affirm and broaden the applicability of the suggested eco-friendly management strategies. Additionally, longitudinal research could yield valuable insights into the enduring effects of these strategies on both the golfing industry and surrounding communities. While this study acknowledges the limitations of word cloud visualization in providing detailed network analyses, future research should consider the incorporation of advanced tools like VOSviewer and Citespace to offer more comprehensive insights. The current study also recognizes the limitation of not utilizing the WOS or Scopus databases, both of which could provide a more thorough bibliometric analysis. Future research will incorporate these databases to compare insights from the academic literature with those from general news articles, offering a broader perspective on sustainability practices in the golf industry.

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