International Journal of Sport Culture and Science
September 2025 : 13(3)
ISSN : 2148-1148
Doi : 10.14486/IntJSCS.2025.748

Carbon Footprint in Sport Management: A Comparative Analysis of Sustainability Strategies and Organizational Transformation

Taner KARAMAN[1], Damla ÖZSOY[2]
[1]Okan University, Istanbul, Turkey
https://orcid.org/0000-0002-1468-4234
[2] Yalova University, Istanbul, Turkey
https://orcid.org/0000-0002-1879-9370

Email: tnrkrmn@gmail.com, damla.ozsoy@yalova.edu.tr

Type: *Review Article (Received: 30.05.2025 – Accepted: 25.09.2025)*

Abstract

This research investigates the impact of carbon emissions in sports competitions from the perspective of sport management sciences and identifies strategies for building sustainable organizational structures. The study systematically analyzes the main sources of carbon emissions in the sports sector, with travel emerging as the most significant contributor, alongside the use of non-renewable energy, facility construction, and waste generation. Drawing on comparative analyses of cases from Poland, Germany, Austria, and Turkey, the findings reveal that away transportation of sports clubs can account for up to 70% of their total emissions, while reliance on private vehicles over public transportation further amplifies the emission burden. Energy consumption in sports facilities is also found to be a major driver of carbon-based emissions. Although some European clubs have successfully achieved carbon neutrality targets, many organizations continue to rely on greenwashing rather than adopting authentic sustainability policies. The study concludes that reducing carbon emissions in sport management requires not only environmental initiatives but also the integration of corporate responsibility into organizational culture. It recommends that sports organizations adopt renewable energy practices, establish low-carbon operational strategies, ensure transparent reporting, and employ artificial intelligence–supported decision-making mechanisms to effectively manage their processes.

Keywords: Carbon footprint, Sport management, Sustainability

Introduction

With the effects of global warming, carbon emission sensitivity is increasing day by day around the world. Research has revealed that most of the carbon emissions occur at different stages such as travel, energy consumption, facility construction and waste generation (Gandola and Asdrubali, 2024; Su et al., 2025). At this point, the sports industry has been intensively discussed in recent years not only for its economic impacts but also for its environmental footprint. In particular, research on carbon footprint has revealed the direct and indirect impacts of sports organizations, events and clubs on climate change (Khanna et al., 2024). While sports clubs and their fans, who travel a lot, play a leading role in carbon emissions, facilities that are not equipped with renewable energy are another carbon emission problem. Research in the literature also shows that some clubs have taken positive initiatives to achieve a carbon neutrality. For example, it was reported that an ice hockey team in Finland was able to achieve carbon neutrality by reducing carbon emissions by more than 50% (Uusitalo et al., 2024). Similarly, efforts to achieve carbon neutrality are increasing in mass sports such as soccer. For example, in the German Bundesliga, spectator transportation generates 6.0-6.3 kg of CO2 emissions per person per match, with 83% of total fan transportation emissions coming from individual vehicle use (Loewen and Wicker, 2021). Especially in football organizations, fan transportation accounts for 38% of GHG emissions and 25% of energy consumption (Khanna et al., 2024). In English Premier League teams, 1134 tons of CO2 equivalent emissions are generated seasonally from transportation activities alone (Pereira et al., 2019). In Turkey, away matches of professional football teams account for more than 70% of total carbon emissions (Çetin et al., 2024).

The examples illustrate the need to change individual transportation preferences in sports clubs. In the case of the Austrian team Rapid Vienna, fans arriving by car generated 71.6% of total emissions, while those using public transportation accounted for 27.1% (Herold et al., 2024). Similarly, choosing alternative modes of transportation such as trains instead of cars at sporting events has the potential to reduce greenhouse gas emissions by 50% (Herold et al., 2024). Energy efficiency strategies are also being introduced to reduce the carbon footprint of the sports industry. Energy management and sustainability practices of stadiums have been shown to play a key role in emission reduction (Chilvers et al., 2015). Increasing the use of renewable energy, especially in sports facilities, stands out as another important element that strengthens environmental sustainability (Yoon and Choi, 2024).

In mega sporting events, it is estimated that 98.9% of emissions come from participants' travel (McCullough et al., 2023). Especially transportation, facility construction and operational activities are among the main components of the carbon footprint of mega events (Su et al., 2025). Optimization of pre-event travel is considered as a critical factor to achieve carbon neutrality targets for mega events (Su et al., 2025). In the case of football, CO2 emissions from fan transport in the German Bundesliga have been estimated at an average of 268 tons per match per season (Loewen and Wicker, 2021). Studies for Polish football clubs have shown that there is a potential to reduce carbon emissions in away transportation by 34% (Domanski, 2024). In Turkey, due to the use of air travel for away trips, some teams reach serious emission values such as 91,667 kg CO2e per season (Çetin et al., 2024). However, sport organizations' approaches to environmental sustainability are also open to criticism. Simmonds and Pielke (2024) stated that the sports industry often resorts to greenwashing strategies instead of developing real carbon reduction policies. For this reason, it is recommended that organizations should provide transparent carbon emission reporting and set measurable targets (McCullough et al., 2023).

New technologies are also being integrated into the carbon management process. Artificial intelligence-supported models contribute to the development of carbon neutrality strategies in sport events and offer new possibilities in emission estimation and management (Zhang, 2023). Zhang's (2023) study emphasizes the importance of adopting low carbon strategies in the design and management stages of sport events. Reducing environmental impacts is not limited to facilities and travel processes. For example, VOC emissions from human respiration and the reaction of skin oils with ozone in a football stadium have been found to reach levels that can affect local air chemistry (Veres et al., 2013). There is also evidence that soccer matches increase urban carbon emissions by an average of 2% (Jin and Chen, 2024). More broadly, sport also has implications for regional environmental policies. For example, state-supported sports development has been shown to contribute positively to reducing regional carbon emissions (Xi et al., 2023). In the case of Turkey, sports facilities in Ardahan province were found to cause a total of 685,045.21 tons of CO2e emissions annually (Atalay and Demir, 2024). Waste management is another area that has an impact on the carbon footprint of sports organizations. Football clubs in the UK produce 74,000 tons of waste annually and it has been determined that this leads to greenhouse gas emissions equivalent to 2,100 tons of CO2e (Dosumu et al., 2014). In large events such as the Super Bowl, 500 tons of carbon emissions per year are tried to be compensated by planting trees for carbon offsetting purposes (Warne, 2011). All these findings show that sports organizations should develop more holistic, data-based and realistic strategies to reduce their environmental impact. It has become an inevitable necessity for sports clubs to transform their corporate cultures in line with sustainability goals (Varmus et al., 2021) and to make zero waste, low carbon, renewable energy use as basic strategies (Ünal & Bağcı, 2017). While existing studies provide valuable insights into the environmental impacts of sport organizations, most remain descriptive or limited to single-case analyses. There is a clear gap in the literature for systematic and comparative research that simultaneously addresses transportation, facility management, energy use, and organizational strategies within the scope of sport management sciences. This study seeks to fill that gap by conducting a multidimensional comparative analysis of findings from different countries, highlighting sustainability strategies for reducing the carbon footprint, and offering new managerial insights and practical recommendations for fostering a low-carbon transformation in sport organizations.

Material and Method

Ethics committee permission: This research does not involve human participants, surveys, interviews, or experimental procedures requiring ethical approval. The study is based solely on secondary data obtained from published academic articles, reports, and publicly available sources. Therefore, ethics committee permission was not required.

Research Model: The research model of this study is constructed to provide a holistic framework for analyzing the carbon footprint of sport organizations from a managerial perspective. Rather than focusing solely on individual factors, the model positions carbon emissions as the outcome of interconnected domains that require organizational transformation. In this framework, sustainability in sport management is approached as a multidimensional process that links environmental performance with strategic decision-making. The model therefore conceptualizes the reduction of carbon footprint not only as an ecological necessity but also as a managerial responsibility that shapes organizational culture, governance, and stakeholder engagement.

Research Group: Since this study is based on secondary data, no human participants were directly involved. Instead, the research group is defined by the scope of the cases selected for

comparative analysis. The study focuses on sport organizations and leagues from four countries: Germany, Austria, Poland, and Turkey. These countries were chosen because they represent diverse geographical, economic, and managerial contexts, which allows for a meaningful comparison of carbon emission sources and sustainability strategies. Within this framework, professional football leagues and mega sport events serve as the core research group, providing data on transportation, facility management, energy use, and organizational sustainability practices.

Data Collection Tool: The data for this study were collected through a systematic review of secondary sources. Academic journal articles, reports, and case studies published between 2011 and 2025 were identified using databases such as Web of Science, Scopus, and Google Scholar. The search was conducted with keywords including carbon footprint, sport management, sustainability, transportation, and energy use. Studies were included if they provided measurable data or documented strategies on carbon emissions in sport organizations. All selected sources were coded under thematic categories to ensure consistency and reliability in data collection.

Data Analysis: The collected data were analyzed using comparative and thematic analysis techniques. First, information from different studies was categorized into four main themes: (1) transportation and travel emissions, (2) facility construction and energy consumption, (3) waste management and operational practices, and (4) organizational sustainability strategies. Then, findings were compared across cases from Germany, Austria, Poland, and Turkey to highlight similarities and differences. The results were synthesized into tables to provide systematic cross-case evaluations, enabling analytical insights and managerial implications to be derived.

Findings

In this section, carbon emission sources in sports organizations, emission impacts of fan transportation by leagues, strategies and recommendations, impacts of stadiums and facilities on carbon emissions, and emission examples from mega sports events are shared in tables below.

Table 1. Sources of carbon emissions in sports organizations

Emission Source	Description	Source
Fan transportation	38% of emissions (specific to football organizations)	Khanna et al., 2024
Energy consumption	25% of emissions (Stadium, facility use)	Khanna et al., 2024
Individual vehicle use	83% of fan transportation emissions in the Bundesliga	Loewen and Wicker, 2021
Use of Public Transportation	Low rate of 27.1% in Rapid Vienna	Herold et al., 2024
Facility construction and operations	Among the main sources of mega-events	Su et al., 2025

Notes. Table adapted from Khanna et al. (2024), Loewen and Wicker (2021), Herold et al. (2024) and Su et al. (2025).

Table 1 presents the prominent carbon emission sources in sports organizations, their shares in total emissions and sample findings in the related literature. While fan transportation and energy consumption stand out as the largest emission items in football organizations, individual vehicle use is an important source, especially in the German Bundesliga. In the case of Rapid Vienna, the low emission rate of public transportation shows the impact of transportation preferences on emission levels. In mega sports events, facility construction and operational activities are included in the literature as a critical emission source as much as transportation.

Table 2. Carbon emissions related to spectator transportation in different leagues

League / Organization	Emission Value	Note	Source
Bundesliga (Germany)	6.0-6.3 kg CO_2 per capita	Fan transportation per match	Loewen and Wicker, 2021
Premier League (England)	1134 tons CO_2/season	Transportation-related	Pereira et al., 2019
Turkey Super League	Away matches more than 70%	Share in total emissions	Cetin et al., 2024
Polish Leagues	34% mitigation potential	Displacement transportation	Domanski, 2024

Notes. Table adapted from Loewen and Wicker (2021), Pereira et al. (2019), Çetin et al. (2024) and Domanski (2024).

Table 2 comparatively shows the carbon emission levels and the nature of these emissions for professional football leagues in various countries. In the German Bundesliga, the per capita emission from fan transportation per match is 6.0-6.3 kg CO_2. In the English Premier League, the seasonal emission from transportation is calculated as 1134 tons of CO_2. In the Turkish Super League, away trips account for more than 70% of clubs' total carbon emissions. In the case of Polish leagues, it has been shown that carbon emissions from away transportation can be reduced by 34%. This data reveals that differences between leagues are directly reflected in managerial strategies.

Table 3. Sustainability strategies and recommended practices

Strategy/implementation	Description	Source
Renewable energy use	To reduce energy consumption in sports facilities	Yoon and Choi, 2024
Zero waste policies	Recommended practice for carbon neutrality	Ünal and Bağcı, 2017
AI-assisted management	For emission estimation and management	Zhang, 2023
Pre-event travel optimization	To reduce carbon emissions at mega events	Su et al.,2025
Carbon emission reporting	For organizational transparency	McCullough et al., 2023

Notes. Table adapted from Yoon and Choi (2024), Ünal and Bağcı (2017), Zhang (2023), Su et al. (2025) and McCullough et al. (2023).

Table 3 shows the main strategies and practices that contribute to environmental sustainability in the context of sport management. Renewable energy use and zero waste policies are prominent practices in reducing carbon emissions in facility and event management. Artificial intelligence-supported management systems provide scientific infrastructure for clubs in both emission estimations and strategic decision-making processes. In mega sports events, optimizing pre-event travel is considered a critical step towards carbon neutrality targets. In addition, transparent carbon emission reporting contributes to the public accountability of organizations for their environmental responsibilities.

Table 4. Environmental impacts of stadiums and sports facilities

Impact area	Featured findings	Source
Energy management	Critically important	Chilvers et al., 2015
VOC emissions (anthropogenic)	Impact on air quality	Veres et al., 2013
Annual CO_2 emissions of sports facilities (Ardahan example)	685,045.21 tons CO_2e	Atalay and Demir, 2024

Note. Table adapted from Chilvers et al. (2015), Veres et al. (2013) and Atalay and Demir (2024).

Table 4 presents a compilation of studies that address the environmental impacts of sports facilities in different dimensions such as energy management, anthropogenic emissions and

annual carbon emissions. These findings show that the environmental impacts of sports facilities need to be evaluated multidimensionally.

Table 5. Emission sharing at mega sport events

Emission source	Share (%)	Source
Travel of participants	98.9%	McCullough et al., 2023
Energy and waste generation	10-20%	Gandola and Asdrubali, 2024
Facility construction and operations	High	Su et al., 2025

Table 5 summarizes the distribution of carbon emissions generated during mega sport events by source. This data necessitates a re-evaluation of transportation, infrastructure and resource use strategies in the planning and management stages of mega events in terms of environmental sustainability.

Discussion and Conclusion

While much scientific research is conducted for success in world football, it is seen that especially issues such as coaching changes are focused on (Karaman et al., 2025). The findings indicate that the effects of football off the field should be examined in detail as well as success on the field. This study provides a multidimensional analysis of the carbon footprint of sports organizations, systematically examining emission sources, regional differences and sustainability strategies, especially in professional football leagues and mega sport events. The findings in Table 1 reveal that fan transportation and energy consumption are the main emission sources in football events, clearly demonstrating the decisive role of transportation choices on these emission levels. While the high level of individual car use in the German Bundesliga highlights the lack of sustainable transport planning, the low-emission public transport usage rate in the case of Rapid Vienna tangibly demonstrates the impact of transport infrastructure on sustainability performance. The comparative league data presented in Table 2 proves that there are significant differences between leagues in terms of transportation policies, fan behavior and organizational preferences. In the Turkish Super League, away trips account for more than 70% of total carbon emissions per club, indicating that emission mitigation policies at the organizational level have not yet been implemented effectively enough. In contrast, the findings that emissions from away transportation in Poland could be reduced by 34% indicate that tangible improvements are possible through managerial strategies. The findings in Table 5 for mega events show that transportation and infrastructure activities have a critical share in total emissions. Accordingly, it is understood that mega sporting events need to be managed not only in terms of day-of-event operations, but also in terms of pre-event preparation processes. Optimizing pre-event travel planning has become a strategic imperative to achieve carbon neutrality targets.

Effective management strategies for sustainability are embodied in the practices detailed in Table 3. Environmental approaches such as the use of renewable energy, zero waste policies and transparent carbon reporting are critical to institutionalizing environmental responsibility. In particular, artificial intelligence-supported management systems provide clubs with a scientific basis for both emission estimations and environmental decision support mechanisms. The dissemination of these systems encourages data-driven environmental management to become the norm in the sports sector. The studies focused on sports facilities compiled in Table 4 show that facility management requires a comprehensive assessment not only in terms of energy efficiency, but also in terms of anthropogenic emissions and annual carbon emissions. These findings support the need to restructure sports facilities according to sustainability principles and standards.

Studies in the literature indicate that carbon emissions arising from the operational activities of football clubs are particularly concentrated in the dimension of transportation. Khanna (2024) found that fan transportation accounts for more than 70% of total emissions, while Wynes (2021) examined the emissions from air travel in the four major professional sports leagues in North America (NHL, NBA, MLB, NFL) and emphasized a strong relationship between aircraft fuel efficiency and carbon emissions. The findings suggest that the adoption of more efficient aircraft technologies could significantly reduce greenhouse gas emissions. In this context, it is concluded that transportation strategies in sports organizations need to be restructured from an environmental sustainability perspective (Domański, 2024; Wynes, 2021). The research by Farley et al. (2017) aims to examine the travel-related carbon emissions of Division I football teams in the National Collegiate Athletic Association (NCAA) in the United States. In particular, the environmental impacts of restructuring between major conferences, the so-called "Power 5", are the focus of this study. The study uses a combination of the Atmosfair carbon emissions calculator and motor vehicle count data from the American Bus Association to calculate the environmental burden of team transportation. The findings provide important contributions in terms of assessing the impacts of changes in conference structures on air and road transportation from an environmental sustainability perspective. In particular, it is observed that the increase in long-distance displacements causes a significant increase in emissions. The results of the research draw attention to the importance of sustainable transportation policies by systematically revealing the impact of league structuring and travel planning on carbon footprint in sports organizations. Herol et al. (2024) conducted an assessment of the transportation preferences (mode choices) of fans and their carbon footprints related to these preferences for a home match of a football team. As a result of the analysis, it was determined that the total greenhouse gas emission from fans in a single home match was 99,548 kg and approximately 6.0 kg per fan. In particular, fans using private vehicles (automobiles) were found to be responsible for 71.6% of the total emissions, despite making up 42.4% of the total audience. These findings allow for a systematic measurement of fan travel behavior and a comparative assessment of the environmental impacts of different modes of transportation. Cetin et al. (2024) found that there are large differences in the carbon footprint of transportation activities of professional football and basketball teams in Turkey. While air travel stands out as the highest emission source, factors such as league structure, season length and geographical location have a direct impact on teams' carbon emissions. Football teams have higher emissions compared to basketball teams due to longer seasons and longer distances. Teams in the Marmara region have relatively lower carbon footprints as they travel shorter distances. These findings suggest that transportation strategies should be reconsidered in terms of environmental sustainability. Domanski (2024) analyzed the carbon footprint of transportation to away matches of football teams in the Polish Ekstraklasa league and found that the use of greener transportation methods can significantly reduce emissions.

Tree planting is widely used in strategies to neutralize the carbon footprint of sports leagues and events. TSG Hoffenheim club encouraged fans to plant trees in Africa with every ticket purchase through the "climate ticket" (Orr & Inoue, 2019). The planting of 140,000 trees at the 2019 Paris Marathon is part of the event's effort to achieve carbon neutrality goals. This practice demonstrates that afforestation strategies can be used effectively to support environmental sustainability in sports organizations (McGuire, 2019).

Conclusion

This study assessed the sources of carbon footprint and mitigation strategies from a sport management perspective, focusing on how the environmental impacts of sport organizations

can be transformed through managerial approaches. The findings clearly show that carbon emissions are largely driven by travel (especially individual transport and air travel), energy consumption and facility management. This suggests that sports clubs and organizations should be evaluated not only on sporting performance but also on environmental performance.

Especially in countries such as Germany, Austria and Finland, clubs' efforts to achieve carbon neutrality demonstrate the success of strategic sustainability practices (Uusitalo et al., 2024; Loewen and Wicker, 2021). On the other hand, in the Turkish case studies (Çetin et al., 2024; Atalay and Demir, 2024), it was observed that emission sources are mostly due to uncontrolled transportation and fossil fuel-based facility management. This suggests that corporate environmental awareness is not sufficiently established in developing countries. Furthermore, an important finding to be discussed is that sports organizations sometimes limit their sustainability claims to greenwashing strategies (Simmonds and Pielke, 2024). This further increases the importance of transparent data sharing and measurable targets. Failure to clearly report the impact of methods used to reduce carbon emissions undermines public trust and the legitimacy of environmental sustainability claims.

The integration of artificial intelligence-supported decision support systems (Zhang, 2023) with carbon forecasting models offers managers the opportunity to make healthier planning. At this point, sport management science should be not only a practitioner but also a guiding field that will enable managers in decision-making positions to develop strategic reflexes against the climate crisis. As a result, the goal of reducing the carbon footprint of sports organizations should be considered not only as an environmental responsibility but also as managerial rationality, corporate dignity and ethical responsibility towards future generations. It is clear that the science of sport management plays a critical role in this transformation, and the concept of environmental sustainability has become one of the key components of managerial strategies.

In conclusion, environmental sustainability in sport organizations is not only an ethical responsibility but also a strategic, managerial, and technological transformation. In this context, the sustainable re-planning of transportation infrastructure, the transition of facilities to environmentally friendly energy systems, the integration of artificial intelligence and digital decision support tools, and the implementation of transparent emission reporting systems stand out as key steps for sustainable sports management. Future research could contribute to developing a more inclusive vision of sustainability by examining the economic viability of these strategies, their impact on stakeholders and the level of engagement of sports consumers.

REFERENCES

Atalay, A., & Demir, S. (2024). Sports, environment and climate change: The carbon footprint of sports facilities based on energy consumption in Turkey. *Baltic Journal of Sport and Health Sciences*, 2(133): 13–23.

Chilvers, S., Chaer, I., & Ford, A. (2015). *Environmental impact and energy management of sports stadia.* CIB Joint International Symposium: Going North for Sustainability. LSBU, London 23 - 25 Nov 2015 London South Bank University.

Çetin, A., Pekel, A., Ozman, C., Ozgur, B., & Demir, A. (2024). Comparative analysis of carbon footprints from away and home matches: A study on leading basketball and football teams in Türkiye. *Sustainability*, 16(21): 9269.

Domanski, R. (2024). The impact of football teams' transportation on the carbon footprint for away matches. *Sustainability*, 16(11): 4721.

Dosumu, A., Colbeck, I., & Bragg, R. (2014). Greenhouse gas emissions: Contributions made by football clubs in England. *Atmospheric and Climate Sciences*, 4(4): 642–652.

Farley, B., DeChano-Cook, L.M. & Hallett, L.F. (2017). Environmental impact of power five conference realignment. *Geogr. Bull.—Gamma Theta Upsilon*, 58: 93–106.

Gandola, D. M., &Asdrubali, F. (2024). A methodology to evaluate GHG emissions for large sports events. *Sustainability*, 16(4): 1504.

Herold, D. M., Breitbarth, T., Hergesell, A., & Schulenkorf, N. (2024). Sport events and the environment: Assessing the carbon footprint of spectators' modal choices at professional football games in Austria. *Journal of Cleaner Production*, 452: 142259.

Jin, J., & Chen, J. (2024). The impact of urban soccer events on carbon emissions: Panel threshold analysis for Chinese cities. Journal of Infrastructure, *Policy and Development*, 8(13): 8947.

Karaman, T., Özsoy, D., & Akyüz, O. (2025). Successful Reflection of Technical Director Changes on Sportive Management in Football. *Turkish Journal of Sport and Exercise*, 27(1): 20-27. https://doi.org/10.15314/tsed.1463945

Khanna, M., Daddi, T., Merlo, F., &Iraldo, F. (2024). An assessment on the carbon footprint of a football club—An action research from theory to practice. *Circular Economy and Sustainability*, 4: 1587–1612.

Loewen, C., & Wicker, P. (2021). Travelling to Bundesliga matches: the carbon footprint of football fans. *Journal of Sport ve Tourism*, 25(3): 253-272. https://doi.org/10.1080/14775085.2021.1932562

McCullough, B. P., Collins, A., Roberts, J., &Villalobos, S. (2023). Sport events and emissions reporting: An analysis of the Council for Responsible Sport standard in running events. *Sustainability*, 15(19): 14375.

McGuire, J. (2019). *Paris Marathon Becomes the First Carbon Neutral Marathon in the World.* https://www.runnersworld.com/uk/training/marathon/a29808666/paris-marathon-carbon-neutral/ Accessed on Oct 7, 2024.

Orr, M., & Inoue, Y. (2019). Sport versus climate: Introducing the climate vulnerability of sport organizations framework. *Sport Management Review*, 22: 452–463.

Pereira, R. P. T., Filimonau, V., & Ribeiro, G. M. (2019). Score a goal for climate: Assessing the carbon footprint of travel patterns of the English Premier League clubs. *Journal of Cleaner Production*, 227: 167-177.

Simmonds, R., & Pielke, R. A. (2024). *Sport at the climate crossroads: champions for climate or green-sportwashing?*, 386–398. Edward Elgar Publishing.

Su, X.-Z., Chen, L., & Xu, X. L. (2025). Carbon emission and energy risk management in mega sporting events: Challenges, strategies, and pathways. *Frontiers in Environmental Science*, 12: 1513365.

Uusitalo, V., Halonen, V., Koljonen, H., Heikkinen, S., &Claudelin, A. (2024). In search for climate neutrality in ice hockey: A case of carbon footprint reduction in a Finnish professional team. *Journal of Environmental Management*, 355: 120455.

Ünal, H., & Bağcı, E. (2017). Sports organizations in the light of environmental sustainability and ecological footprint. *Journal of Human Sciences*, 14(3): 3006–3021.

Varmus, M., Kubina, M., & Adamik, R. (2021). *Sustainable Management of Sports Organizations* (87–142). Springer, Cham.

Veres, P. R., Faber, P., Drewnick, F., Lelieveld, J., & Williams, J. (2013). Anthropogenic sources of VOC in a football stadium: Assessing human emissions in the atmosphere. *Atmospheric Environment*, 77: 1052–1059.

Warne, K. (2011). *The Carbon Sleuth* (94–106). Island Press.

Wynes, S. (2021). COVID-19 Disruption Demonstrates Win-Win Climate Solutions for Major League Sports. *Environmental Science and Technology*, 55: 15609–15615.

Xi, M., Wang, D., & Xiang, Y. (2023). Fiscal expenditure on sports and regional carbon emissions: Evidence from China. *Sustainability*, 15(9): 7595. https://doi.org/10.3390/su15097595

Yoon, T., & Choi, Y. H. (2024). Strategies for Improving Environmental Sustainability in Sports Facilities: Case Analysis and Actionable Takeaways. *Journal of Sport and Dance Science*, 4(2): 25–35.

Zhang, Y. (2023). Artificial intelligence carbon neutrality strategy in sports event management based on STIRPAT-GRU and transfer learning. *Frontiers in Ecology and Evolution*, 11: 1275703.