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The Evolution, Strategic Significance, and Future Trends of Research in Sports Facilities Maintenance Management

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Abstract: *Maintenance management plays a pivotal role in the field of sports facilities. This study searches for "Maintenance Management of Sports Facilities" in core journals listed in the WEB OF SCIENCE、Scopus and EI databases, using word frequency statistics and co-word analysis, along with SPSS and COOC bibliometric software for relevant data and graphical analysis. The results indicate that the hotspots in the research of maintenance management in sports facilities focus on topics such as "Lifecycle and Facilities Management," "Project Management and Preventive Maintenance," "Risk Management, Built Environment, Energy Efficiency," "Costs," and "Sustainable Development and Artificial Intelligence," with detailed analyses. It is hoped that this will provide important references for research in the field of sports facility maintenance management and promote the deeper application and development of maintenance management in the management practices of sports facilities.*

Keywords: Sports Facilities; Maintenance Management; Facility Management

1. Introduction

Sports facilities are form the crucial material basis and precondition for the basic public sports service system (Zhu, Gao, Zhu, & Zhang, 2020). The construction of public sports facilities in our society has received significant attention, and studying the current utilization of public sports facilities in China holds substantial significance for promoting national investments in sports (Zhu, 2015). In recent years, there have been some advancements in the operation and maintenance of buildings; however, the efficiency of maintenance practices remains low, leading to considerable energy waste (Bouabdallaoui, Lafhaj, Yim, Ducoulombier, & Bennadji, 2021). Additionally, the issue of poor maintenance not only concerns sports facilities but is also a national issue affecting the management of government assets and all government-owned places (Harun, Salamudin, & Hushin, 2013).

Therefore, conducting research on the maintenance management of sports facilities holds significant academic and practical value. The necessity for maintenance management of sports facilities primarily stems from its fundamental requirement for safety. Poorly managed sports facilities may lead to functional disruptions or even cause safety incidents, endangering the lives and property of the general public. Furthermore, from the perspective of optimizing resource allocation, effective maintenance management can enhance facility efficiency, extend their lifespan, and reduce resource waste and environmental impact, which is particularly crucial in the context of scarce resources.

The maintenance management of sports facilities combines theories and methods from multiple disciplines, including construction engineering, management science, and sports science, making it an interdisciplinary research field. This research not only enriches the theoretical foundation of sports facility maintenance management but also, from a practical application standpoint, guides the maintenance practices of sports facilities, optimizes maintenance management processes, enhances facility performance, and ensures safety and user satisfaction, offering significant social and economic benefits. This study aims to systematically analyze the theories and practical research on sports facility maintenance management by numerous scholars, examine current research hotspots, propose future research directions and focuses, thereby providing scientific decision support for the sustainable management of sports facilities.

2. Data Source, Cleaning, and Research Methods

2.1 Data Source and Cleaning

The data used in this paper comes from core journal articles in the WEB OF SCIENCE, Scopus, and EI databases. The search was conducted using two sets of keywords: the first set includes "Sports facilities, Athletic facilities, Sports complexes, Recreational facilities, Gymnasiums, Sport centers, Athletic centers," and the second set includes "maintenance management, Service management, Upkeep management, Asset management, Facilities management, Care management, Operational management." A cross-search was performed to retrieve high-quality literature directly relevant to the research topic, up until August 22, 2024, totaling 371 articles. After removing duplicates, 354 articles remained. After excluding articles with missing keywords, 329 articles were counted. After reading the themes and abstracts of the selected literature and extracting key information and data on the research topic of sports facility maintenance management, 124 articles remained. This study focuses on critically analyzing the quality and methods of the existing literature. Based on this analysis, a comprehensive literature review is written, summarizing the findings of existing research and outlining future research directions.

2.2 Research Method

Co-word analysis is a quantitative method used to analyze the patterns of keyword co-occurrence in literature, widely used in scientometrics and knowledge management. By analyzing the co-occurrence network of keywords, it reveals the relationships between research topics and the structure of academic fields. Researchers can identify hotspots and trends in the scientific field, as well as the relationships between different concepts or topics.

This paper primarily uses SPSS software and COOC bibliometric software to analyze the high-frequency keywords of sports facility maintenance management research papers and construct a co-occurrence matrix of high-frequency keywords. Cluster analysis is performed to organize and analyze the research themes of sports facility maintenance management, examine why maintenance management is very important in the field of sports facility management, and provide suggestions for the research of sports facility maintenance management in China.

3. Basic Analysis of Research Results

3.1 Annual Publication Volume and Cumulative Analysis

After a thorough analysis of the annual publication volume and cumulative changes in the research of sports facility maintenance management, it is evident that this field has experienced significant development over the past twenty-four years, as shown in Figure 1. The left graph

shows the annual publication volume, while the right graph represents the cumulative publication volume.

The annual publication volume in the field of sports facility maintenance management shows significant volatility, especially between 2000 and 2005 when the publication volume was lower, and even between 2007 and 2009 when no related research was published. This may reflect a lack of innovative momentum in the field during that period. However, starting from 2011, the publication volume gradually increased, particularly during 2014 to 2015 and from 2020 to 2022, which suggests that new research topics or technologies may have emerged during these periods, possibly driven by policy and market demands. Further thematic analysis will provide more insights.

The continuous growth in cumulative publication volume reflects the increasing knowledge accumulation and academic depth in the field of sports facility maintenance management. From a long-term trend, the cumulative publication volume increased from 4 articles in 2001 to 120 articles in 2024, marking the field's gradual shift from a marginal to a significant branch of sports science research. Especially since 2015, the rapid increase in cumulative publication volume may be closely related to the global emphasis on health and physical activities, as well as the development of digital technologies.

The research heat in sports facility maintenance management has significantly increased in recent years, reflecting the growing global concern over the efficiency and safety of public sports facilities. Additionally, the periodic fluctuations in the research also suggest the impact of research funding and policy orientation on research activities. Given the recent research activity, future studies may continue to focus on enhancing the sustainability and cost-effectiveness of facilities, as well as integrating emerging technologies to optimize maintenance management strategies.

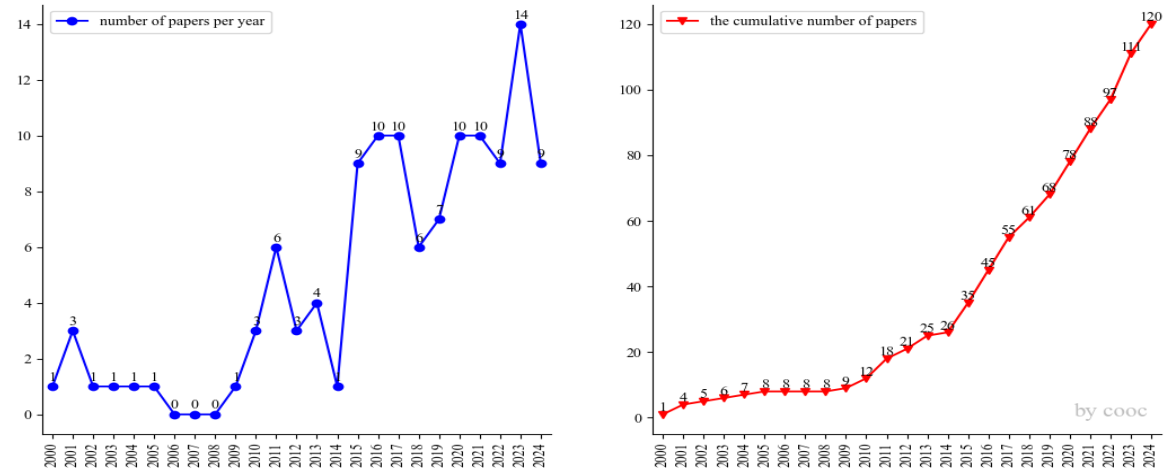

Figure 1: Changes in the annual and cumulative number of research papers on sports facility maintenance management

3.2 Keyword Frequency Analysis

Keywords directly represent the content of the research in articles. Conducting frequency statistics and co-word analysis on keywords can reflect the research themes in the field of sports facility maintenance management. Using COOC bibliometric software to extract keywords and conduct frequency statistics, the 124 research papers on sports facility maintenance management contain a total of 801 keywords. After merging and removing synonymous or

meaningless keywords and arranging them in descending order of frequency, 13 high-frequency keywords with a frequency of ≥4 are listed, as shown in Figure 2.

Among them, "sports facilities" and "recreational facilities" are the main keywords of this study and appear frequently, which is logical. Under the research context of sports facility maintenance management, the terms "sustainable development" and "sustainability" appeared 24 times, and were uniformly categorized under "sustainable development." This emphasizes the balance among environmental, economic, and social dimensions, with the research focusing more on the positive impacts during the facility construction and maintenance management processes and on resource efficiency.

The term "built environment" in the field of sports facilities includes building ecology, ergonomics, and environmental psychology, focusing on how facility design can affect the later maintenance management of sports facilities and how it influences athletic performance and spectator experience.

Keywords such as "facility management," "risk management," "energy efficiency," "lifecycle," "costs," "preventive maintenance," and "project management" are crucial in the research on maintenance management of sports facilities. They involve predictive maintenance, optimization of resource allocation, and risk assessment. They may also cover how to enhance energy efficiency through technological and managerial innovations, as well as how to identify and mitigate potential maintenance management risks. Furthermore, these keywords explore how measures can be taken during the design, construction, and maintenance stages to reduce overall costs and enhance the long-term value of facilities.

Additionally, the term "artificial intelligence," in the context of the digital technology era, likely discusses how to utilize big data and intelligent algorithms, and apply advanced planning and monitoring tools to optimize the maintenance management process of sports facilities. Overall, these keywords reflect the multidimensionality of research in sports facility maintenance management. They enable a deeper understanding of the complexity within the field of sports facility maintenance management and provide theoretical support to guide practical operations and policy-making, thus promoting the scientific development and technological innovation in this field.

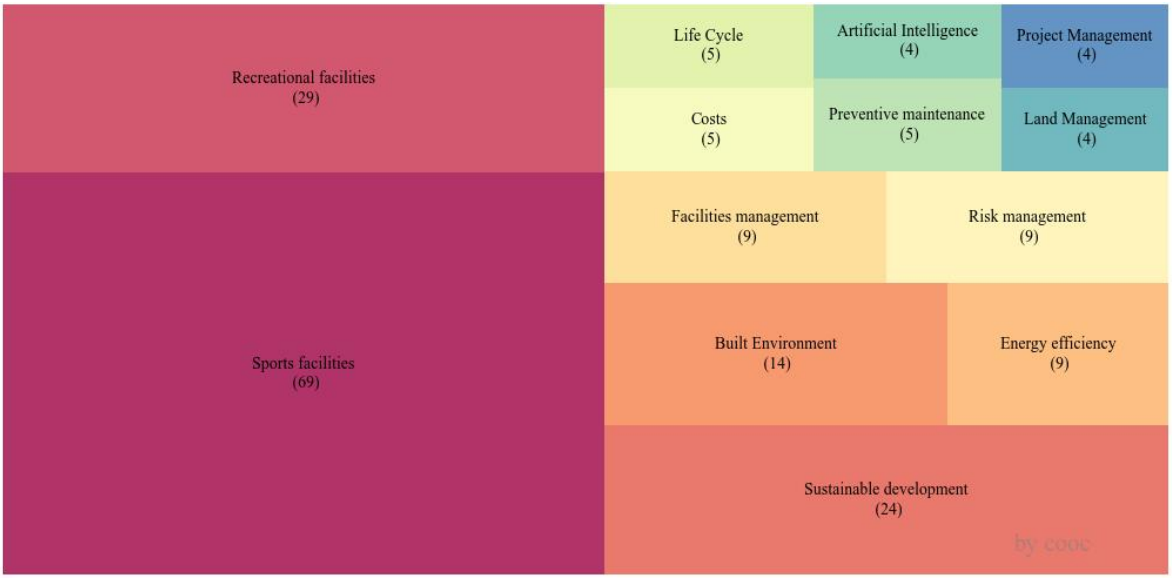

Figure 2: High-Frequency Keywords in Research Papers on Sports Facility Maintenance Management

From Figure 3, it is evident that between the years 2000 and 2024, the annual frequency of mentions of various keywords in the research on sports facility maintenance management varied. It is apparent that sports facilities have always been a focal point, with peak attention occurring in 2007, which coincides with major sporting events driving research into sports facility management technology.

The focus on sustainable development within sports facility maintenance management research began to significantly increase in 2010, especially peaking in 2013. This rise corresponds with the global growing concern for sustainability issues, and how sports facilities can reduce their negative impact through more environmentally friendly construction and maintenance management practices, thus further enhancing sustainability. Artificial intelligence rapidly became a research hotspot after 2017, indicating a trend in the application of new technologies in sports facility maintenance management, potentially involving maintenance management systems. The integration of sustainable development and artificial intelligence is also becoming more closely linked.

The attention to risk management had significant peaks in 2009 and 2014, reflecting the needs of sports facility maintenance managers for disaster prevention and emergency preparedness, to face global economic instability and natural disasters. The keyword 'energy efficiency' has gradually increased after 2011, aligning with global concerns over reducing energy consumption and carbon footprints, with research likely focusing on how to enhance the energy use efficiency of sports facility maintenance management.

Preventive maintenance is a crucial aspect of sports facility maintenance management. After 2018, it has shown steady growth, gradually becoming a key topic within facility management, aimed at reducing facility breakdowns and maintenance costs.

The annual trend of high-frequency keywords in research papers on sports facility maintenance management indicates that the field is continuously evolving, emphasizing the importance of technological innovation and sustainability. The deepening of research and advancements in technology provide new perspectives and tools for facility management and also hint at potential new directions for future research.

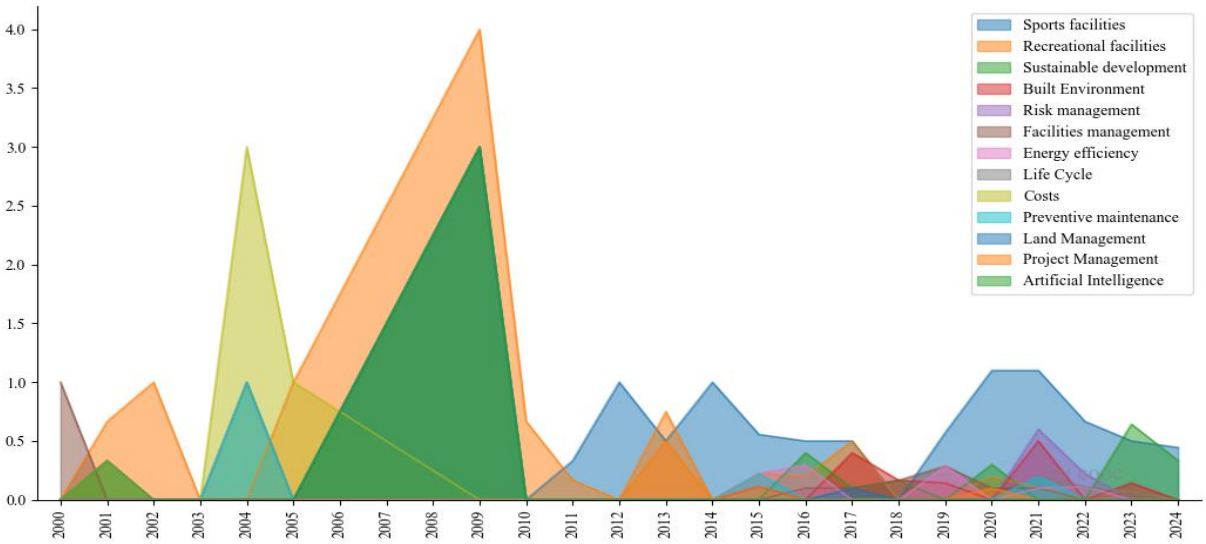

Figure 3: Annual Growth Rate of High-Frequency Keywords in Research Papers on Sports Facility Maintenance Management

3.3 Analysis of Similarity and Dissimilarity Matrices

The research on the maintenance management of sports facilities examines the co-occurrence of 13 high-frequency keywords, constructing a 13x13 keyword co-occurrence matrix, which is then transformed into a similarity matrix as shown in Table 1. In the similarity matrix, values range from 0 to 1, with values closer to 1 indicating greater dissimilarity, and hence a higher degree of similarity between two keywords. Conversely, lower values indicate less similarity. Analyzing this type of matrix not only facilitates a better understanding of the relationships among various research themes but also identifies potential interdisciplinary research opportunities, thereby fostering innovation and development in the field of sports facilities maintenance management.

There is a relatively high correlation (0.834) between facility management and lifecycle, indicating the importance of considering the entire lifecycle in the maintenance management of sports facilities. The correlation between energy efficiency and preventive maintenance reaches 0.486, underscoring the significance of enhancing energy efficiency through preventive measures. Artificial intelligence scores a similarity of 1.440 with cost, highlighting its crucial role in cost management and optimization within the maintenance management of sports facilities.

Table 1: Similarity matrix of high-frequency keywords in research papers on sports facility maintenance management

	Sports facilities	Recreational facilities	Sustainable development	Built Environment	Energy efficiency	Facilities management	Risk management	Life Cycle	Costs	Preventive maintenance	Artificial Intelligence	Land Management	Project Management
Sports facilities	0.88593522	0	0	0	0	0	0	0	0	0	0	0	0
Recreational facilities	0	1.300682935	0	0	0	0	0	0	0	0	0	0.321130007	0
Sustainable development	0	0	1.419742295	0	0	0	0	0	0	0	0	0.475280686	0
Built Environment	0	0	0	2.267040156	0	0	0.033447934	0	0	0	0	0	0
Energy efficiency	0	0	0	0	2.247825591	0	0.244757028	0	0	0.485919085	0	0	0
Facilities management	0	0	0	0	0	2.944438979	0	0.834225779	0	0	0	0	0
Risk management	0	0	0	0.033447934	0.244757028	0	2.63613762	0	0	0	0	0	0
Life Cycle	0	0	0	0	0	0.834225779	0	2.530675068	1.121907851	0.921237156	0	0	0

Costs	0	0	0	0	0	0	0	1.121907851	2.932016459	1.121907851	1.440361582	0	0
Preventive maintenance	0	0	0	0	0.485919085	0	0	0.921237156	1.121907851	2.530675068	0	0	1.239690887
Artificial Intelligence	0	0	0	0	0	0	0	0	1.440361582	0	2.944438979	1.440361582	0
Land Management	0	0.321130007	0.475280686	0	0	0	0	0	0	0	1.440361582	2.708872908	0
Project Management	0	0	0	0	0	0	0	0	0	1.239690887	0	0	2.944438979

To further minimize errors and enhance the clustering analysis and keyword co-occurrence structure analysis, the similarity matrix is transformed into a dissimilarity matrix, as shown in Table 2. The dissimilarity matrix displays the extent of dissimilarity among 13 high-frequency keywords in the research on sports facilities maintenance management. It presents a dissimilarity matrix of high-frequency keywords in research papers on sports facilities maintenance management, used to assess the correlations among these keywords. A matrix value closer to 1 indicates higher correlation; values approaching 0 or lower signify lower correlation.

Table 2: Dissimilarity matrix of high-frequency keywords in research papers on sports facilities maintenance management

	Sports facilities	Recreational facilities	Sustainable development	Built Environment	Energy efficiency	Facilities management	Risk management	Life Cycle	Costs	Preventive maintenance	Artificial Intelligence	Land Management	Project Management
Sports facilities	0	0.910579633	0.852558044	0.903476582	0.879614147	0.959871382	0.959871382	0.89232362	1	0.89232362	1	1	0.879614147
Recreational facilities	0.910579633	-2.22045E-16	0.772570587	0.900741667	0.938101554	1	0.876203108	1	0.91695452	1	0.907152331	0.814304662	0.907152331
Sustainable development	0.852558044	0.772570587	-2.22045E-16	1	0.931958618	0.931958618	1	0.908712907	1	1	0.897937927	0.795875855	1
Built Environment	0.903476582	0.900741667	1	0	0.910912919	1	0.910912919	1	1	1	1	1	1
Energy efficiency	0.879614147	0.938101554	0.931958618	0.910912919	0	1	0.888888889	1	1	0.850928802	1	1	1
Facilities management	0.959871382	1	0.931958618	1	1	0	1	0.850928802	1	1	1	1	1

Risk management	0.959871382	0.876203108	1	0.910912919	0.88888888	1	0	1	1	1	1	1	1
Life Cycle	0.89232362	1	0.908712907	1	1	0.850928802	1	2.22045E-16	0.8	0.8	1	1	1
Costs	1	0.91695452	1	1	1	1	1	0.8	2.22045E-16	0.8	0.776393202	1	1
Preventive maintenance	0.89232362	1	1	1	0.850928802	1	1	0.8	0.8	2.22045E-16	1	1	0.776393202
Artificial Intelligence	1	0.907152331	0.897937927	1	1	1	1	1	0.776393202	1	0	0.75	1
Land Management	1	0.814304662	0.795875855	1	1	1	1	1	1	1	0.75	0	1
Project Management	0.879614147	0.907152331	1	1	1	1	1	1	1	0.776393202	1	1	0

3.4 Analysis of Publication Volume in Journals

Figure 4 is a rose diagram of the publication volume of research journals in the field of sports facility maintenance management. This rose diagram illustrates the publication volume of research papers on sports facility maintenance management across different journals. Each sector represents a specific journal, with the size (angle) of the sector indicating the number of related papers published in that journal, and the varying colors possibly representing different research directions or themes.

For instance, "Sustainability (Switzerland)" demonstrates a high focus on sustainability research. Given that sustainability is a hot topic in sports facility maintenance management, there is a significant volume of publications in this field. "Facilities" indicates that research on sports facility maintenance is relatively concentrated in this journal, including aspects such as the design, operation, maintenance, and management strategies of sports facilities.

The sectors for "Sensors" and "Open Cybernetics and Systemics Journal" indicate an increasing application of technology and systems methodologies in the management of sports facilities, aimed at optimizing the operation and maintenance of these facilities. Overall, this diagram showcases the diversity and interdisciplinarity of research in sports facility maintenance management. The focus of different journals reveals various dimensions of research in this field, providing a better understanding of research trends and directions in the academic community. Future efforts should continue to promote interdisciplinary cooperation and conduct targeted regional research to enhance the maintenance management level of sports facilities.

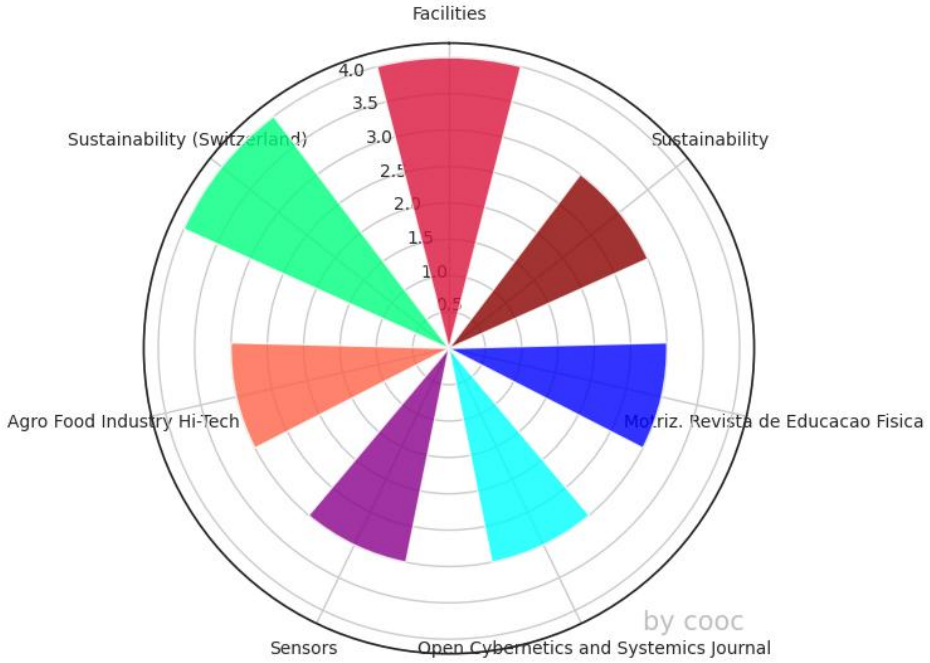

Figure 4: Rose Diagram of Publication Volume in Journals for Research on Sports Facility Maintenance Management

3.5 Cluster Analysis

The dendrogram of high-frequency keywords in research papers on sports facility maintenance management presents the clustering results of keywords, revealing relationships and similarities between different research themes. By analyzing these clusters, we can better understand the research trends and interdisciplinary connections within the field of sports facility management.

The close clustering of "lifecycle" and "facility management" suggests that researchers often combine the entire lifecycle of a facility (which includes design, construction, operation, maintenance, and disposal) with the strategies and practices of daily management. This is similar to having a comprehensive game plan in sports that covers everything from training to game day strategies, enhancing the operational efficiency and lifespan of sports facilities.

The integration of "project management" and "preventive maintenance" highlights how good project management in sports facility maintenance not only involves direct execution of projects but also includes extending the lifespan of sports facilities and reducing maintenance costs through preventive measures. This approach can be likened to a regular training regimen for athletes that prevents injuries and enhances performance longevity.

The clustering of "risk management," "built environment," and "energy efficiency" indicates that effective risk management strategies in sports facility maintenance must consider the characteristics of the built environment and energy efficiency. This reflects a growing focus in modern sports facility maintenance on integrating environmental sustainability and energy efficiency for comprehensive risk management, akin to how a coach might strategize taking into account both the strengths and weaknesses of the team and external conditions.

The keyword "cost" underscores the independent importance of cost control in sports facility maintenance management. Effective maintenance management can reduce maintenance and operational costs, involving financial allocation, cost-benefit analysis, and budget control. This

is akin to managing a sports team's budget to ensure maximum efficiency in spending, ensuring funds are allocated where they yield the most benefit.

The pairing of "sustainable development" and "artificial intelligence" emphasizes how modern technology is increasingly integrated into the design, operation, and maintenance of sports facilities, aiming to achieve sustainability in environmental, economic, and social aspects. This integration can be compared to using advanced sports analytics to enhance team performance and strategy planning.

In summary, the cluster analysis not only identifies core research themes within the field of sports facility maintenance management but also explores how these themes interact and impact each other in practical applications. This is crucial for guiding both academic research and practical applications. Research in sports facility maintenance management revolves around key themes such as "maintenance management," "lifecycle and facility management," "project management and preventive maintenance," "risk management, built environment, energy efficiency," "costs," and "sustainable development and artificial intelligence." The following sections will focus on analyzing these key groups of research themes.

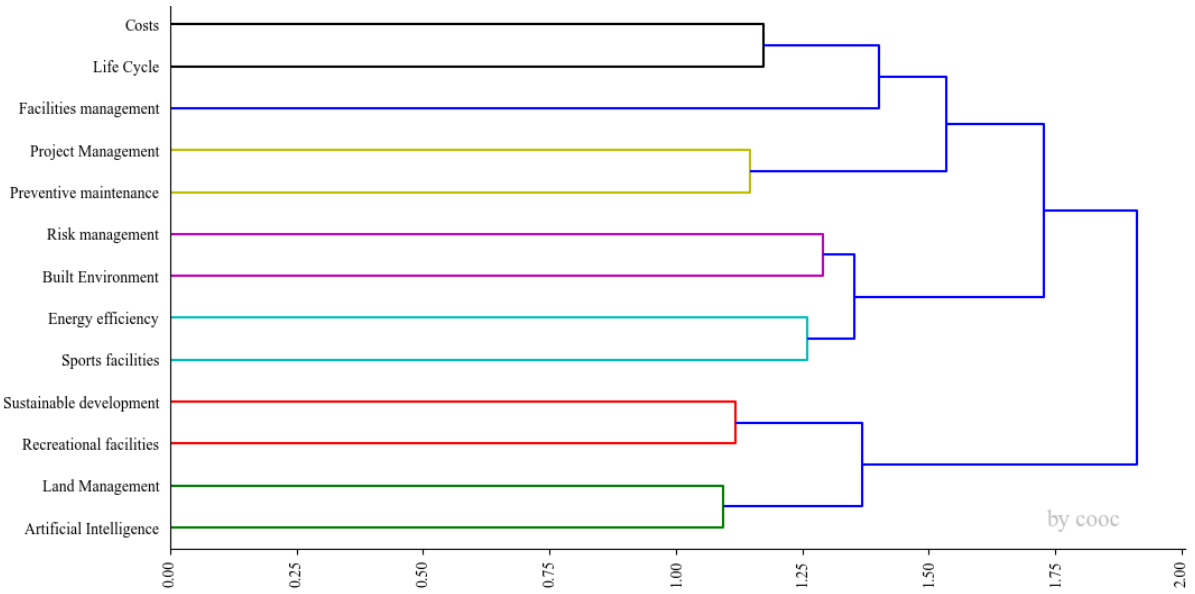

Figure 5: Dendrogram of High-Frequency Keywords in Research Papers on Sports Facility Maintenance Management

3.6 High-Frequency Keyword Bubble Chart

The high-frequency keyword bubble chart displays the correlation analysis of high-frequency keywords in research on sports facility maintenance management, illustrating interactions between different research themes. Each bubble represents the frequency of mention of a specific keyword in a particular year, and the size of the bubble indicates the relative importance or volume of research on that keyword.

The bubbles for "sports facilities" and "recreational facilities" are relatively large throughout the timeline, indicating that these two keywords are central to research in sports facilities. Although smaller, the bubbles for "project management" and "preventive maintenance" persist, demonstrating their ongoing importance in maintaining sports facilities.

During the 2008 financial crisis and the following years, the bubble for "risk management" grew, likely reflecting an increased need for risk assessment and management in sports facility maintenance due to heightened economic uncertainty. The bubbles for "sustainable development" and "artificial intelligence" have noticeably increased in recent years, showing a significant rise in focus on these keywords in sports facility maintenance research. This suggests that the application of artificial intelligence in sports facility maintenance is gaining importance. Additionally, since the early 2010s, the bubble for "energy efficiency" has gradually grown, aligning with global trends towards improved energy efficiency and reduced carbon emissions.

Analyzing the bubble chart can forecast future research directions in sports facility maintenance management, particularly focusing on sustainable development and artificial intelligence. This analysis is valuable for guiding academic research, policy-making, and practical management practices.

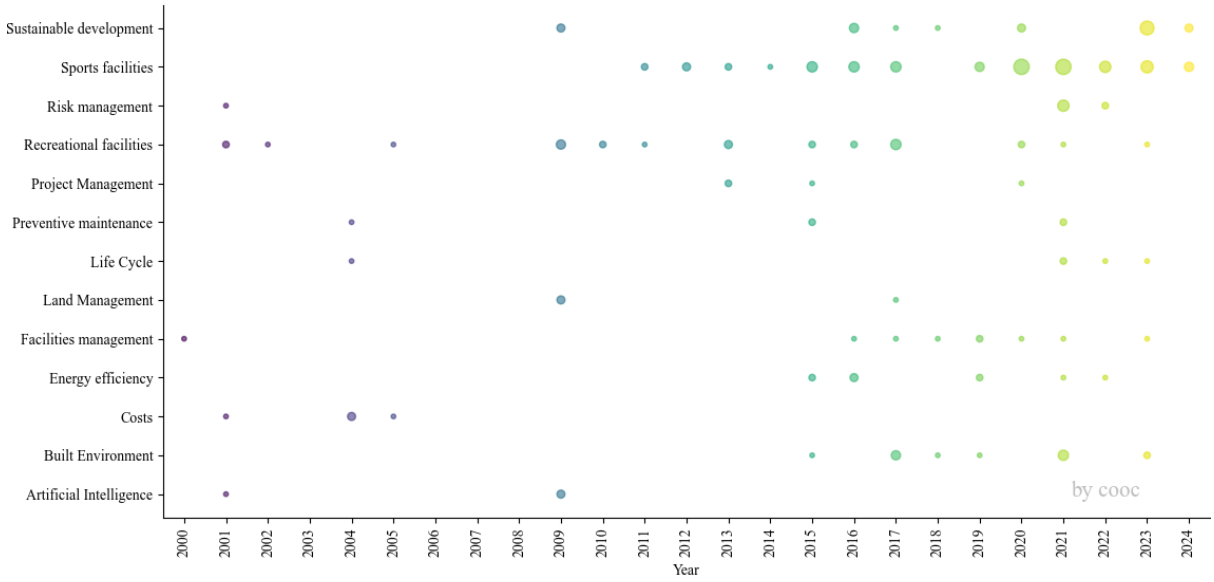

Figure 6: Confusion Bubble Chart of High-Frequency Keywords in Research Papers on Sports Facility Maintenance Management

4. Analysis of Research Themes in Sports Facility Maintenance Management

Research in sports facility maintenance management has generated a series of key phrases revolving around "maintenance management." This study mainly analyzes five significant themes: "lifecycle and facility management," "project management and preventive maintenance," "risk management, built environment, energy efficiency," "costs," and "sustainable development and artificial intelligence."

4.1 Lifecycle and Facility Management

Boussabaine & Kirkham (2004) Maintenance costs, especially for highly demanded public sector facilities, can represent a large portion of the total lifecycle costs. Lau, Hou, Lai, Edwards & Chileshe (2021) They emphasize distinguishing the relative importance of different swimming pool components and prioritizing resources for maintenance and management. The assessment framework and research results provide facility managers with crucial benchmarks for optimizing the performance of these sports facilities, aiding stakeholders in making evidence-based decisions throughout the lifecycle of sports facility development and management.

Omayer & Selim (2022) Discuss the application of Building Information Modeling (BIM) in facility management to address current industry challenges regarding the interaction between BIM and Facility Management (FM). The construction project involves the role of BIM and Construction Operation Building information exchange (COBie) in sports facilities and operations and maintenance (O&M) information, reviewing the benefits of BIM based on experiences in the Arab world's construction sector. Bueno, Mazzei, Scaglia & Almeida (2020) Using tools like GIS to generate public profiles around sports facilities, it is possible to determine which sports projects each facility should prioritize, thereby improving the management of sports-related public policies.

Brinkoe & Nielsen (2018) The study's results increased understanding of the processes involving shared spaces within facility management environments and proposed specific recommendations concerning locality, engagement, and practicality issues. Gobikas & Čingienė (2021) From improving infrastructure and increasing sports participation to successfully managing competition and having a constructive impact on establishing more effective regulatory frameworks, this governance model shows potential for the future.

Güngör & Polat (2017) Determine the current status of urban parks in Konya Province and the quality, adequacy, growth rate, and maintenance of park facilities. The survey results show that 44.1% of users report that park maintenance is good. Jenkins, Yuen, Rose, Maher, Gregory & Cotton (2015) Study surveyed quality differences in park recreational spaces between affluent and non-affluent neighborhoods in a metropolitan area in the southeastern United States, covering three environmental characteristics of PSQAT: location, recreational value, and the upkeep and maintenance of two urban parks. This suggests that children and young people might have different experiences of local play spaces, thus possibly gaining different physical and mental health benefits.

Sharma & Chaudhary (2021) Estimates that the lack of physical exercise is the highest in South Asia at 34%, aiming to promote physical exercise through interventions such as outdoor gyms, which are becoming increasingly popular worldwide. The main improvement suggestions are to increase the number of outdoor fitness equipment installations, regularly maintain the equipment, and staff the site with fitness trainers.

In summary, these studies collectively emphasize the need for a comprehensive facility management approach to manage and maintain sports facilities, covering various factors from initial planning to the end of the lifecycle, ensuring sustainability and effectiveness throughout their lifecycle.

4.2 Project Management and Preventive Maintenance

Harun, Salamudin & Hushin (2013) conducted a study that gathered vital information related to the maintenance management practices of public sports facilities managed by Malaysian sports stadium companies. The study focused on characteristics, facility maintenance information, and levels of effectiveness. From the scores of maintenance success factors, the results show that 85.3% of Malaysian sports stadium companies were rated as moderately satisfactory, while 2.9% were rated as excellent.

Paterson (2013) believes that evaluating the potential uses of public domain spaces and soliciting opinions from various users are essential. It is necessary to consider the views of potential users, and project management requires a strong and consistent coordinator whose

responsibilities encompass design, use, and maintenance. Marinelli (2020) argues that a design management model based on Building Information Modeling (BIM) is particularly suitable because it allows for sharing, visualization, estimation, and resolving design changes without the need for time-consuming paper transactions.

The Geraldo Magalhães-Geraldão sports arena, built in 1970, had been neglected by authorities in terms of maintenance and necessary upgrades for many years. To get back on track for hosting major sports events, a project was devised to renovate the main arena and new structures to support athletic training. Visual inspections were conducted to assess the existing pathological manifestations before initiating structural repairs, showing that if preventive maintenance had been performed, costs could have been reduced from R$583.33 per square meter to R$116.67 per square meter (de Sousa Neto, Berenguer, Barreto, e Silva, Lins, & Monteiro, 2015).

Bouabdallaoui, Lafhaj, Yim, Ducoulombier & Bennadji (2021) proposed a predictive maintenance framework based on machine learning technology. This framework is designed to guide the implementation of predictive maintenance in building facilities. It is divided into five steps: data collection, data processing, model development, fault notification, and model improvement, providing guidance to scientists and practitioners on implementing predictive maintenance methods in buildings.

In conclusion, in modern sports facility management, integrating project management with preventive maintenance is a key strategy for maintaining long-term stable operations and reducing maintenance costs. This integration maximizes cost-effectiveness, ensuring that sports facilities can support high-quality sports activities and events.

4.3 Risk Management, Built Environment, Energy Efficiency

Accurately predicting safety risks is key to ensuring structural safety (Shi, Liu, Meng, & Wang, 2023). Zhu (2015) analyzes the current use of public sports facilities in China, recommending the demolition of underused sports facilities in densely populated areas and parks, emphasizing the importance of facilities for the elderly in communities and district-level fitness centers, and focusing on the maintenance of old sports facilities. Shin, Jaakson & Kim (2001) aim to manage the physical environment of recreational activities, suggesting that the built environment can influence the physical health of youths through encouraging physical activities (Bezold, Stark, Rundle, Konty, Day, Quinn, Neckerman, & Roux, 2017).

To ensure athletes' health, well-being, and performance, optimal indoor air quality, regular maintenance, and ventilation of sports facilities are crucial (Peixoto, Pereira, Morais, & Slezakova, 2023). Bralewska, Rogula-Kozłowska & Bralewski (2022) aimed to determine the concentration of selected gaseous indoor air pollutants (CO2, VOC, NO2, SO2) and evaluate the efficiency of ventilation systems to determine factors that affect air quality in a typical Polish sports center. The results can be used to develop appropriate control strategies to improve indoor air quality in sports facilities and minimize adverse health effects due to poor air quality. Fitness centers should consider conditions conducive to microbial proliferation (Ramos, Viegas, Verde, Wolterbeek, & Almeida, 2016), and factors affecting satisfaction with sports venues include accessibility, fresh air, cleanliness, and affordability. Residents' main demands for recreational environment improvement include providing more types of sports facilities and venues and strengthening the maintenance and management of sports facilities (Wu, Qin, & Zhou, 2018).

Not only is risk management extremely important in sports facility maintenance management, but the built environment and energy efficiency also show their key role in reducing maintenance costs. By remodeling sports facilities, there is a significant opportunity to save energy (Kim, Sunitiyoso, & Medal, 2019). Large venues often face criticism for high resource and energy consumption, potential environmental pollution, and the massive costs of construction and operation, as well as underutilization post-events, considered unsustainable. By remodeling these facilities, there is a significant opportunity to save energy. Decisions on remodeling involve many stakeholders and several interrelated factors, highlighting major focal points—economic viability, resident impact, and technical practicality (Kim, Sunitiyoso, & Medal, 2019).

Park & Kwon (2018) managed to significantly reduce the maintenance and operational costs of a major sports venue—the main stadium of the Busan Asian Games—by installing renewable power generation modules to meet power needs, using "multiple energy mix optimization" software for simulation. The results aimed to simulate and demonstrate the optimal configuration of the renewable power generation system, proposing a photovoltaic-wind turbine-battery-converter setup with an energy cost of $0.491 per kWh, achieving 100% renewable energy. Fantozzi, Leccese, Salvadori, Rocca & Garofalo (2016) determined general criteria for assessing the techno-economic sustainability of using LED lighting in indoor sports facilities, highlighting solutions using LED floodlights that have the highest energy efficiency.

Park, Kwon & Del Pobil (2016) studied the potential configurations of the JWCS standalone renewable power generation system using HOMER software. Simulation results produced three optimal system configurations, where the proportion of renewable energy was 1.00, with relatively lower energy costs ($0.405, $0.546, and $0.692 per kWh). Marion & Wimpey (2017) aimed to simulate and elucidate factors significantly impacting soil erosion on trails, which can be manipulated by trail professionals to sustain high traffic while minimizing soil erosion.

In summary, through the measures discussed above, sports facility managers can effectively enhance the safety, comfort, and economic efficiency of maintenance management. At the same time, they contribute to environmental protection and community welfare, aiding in the long-term sustainable development of sports facilities.

4.4 Costs

Maintenance and operating costs constitute a significant portion of the total operating costs of facilities (Boussabaine, 2001). Financial demands represent the greatest challenge in implementing sustainable measures (Stinnett & Gibson, 2016). Harun, M. Salamudin & Hushin (2013) noted that public sports facilities in Malaysia are assets into which the government has invested heavily. Boussabaine & Kirkham (2004) highlighted that the ability to accurately predict these maintenance costs can provide crucial management tools during the operational phase. A thorough investigation of existing technologies and metrics for predicting these costs laid the foundation for this study, which proposed an innovative simulation-based method for modeling maintenance costs of sports buildings for local authorities in the UK. The study findings indicated that total building area, pool size, and user numbers are key factors affecting the maintenance costs of sports center buildings.

After hosting the World Cup in 2002, local governments in Korea were responsible for managing several large football stadiums. Despite significant efforts by these governments to profit from these venues, it proved too difficult for several of them to recover all operational, maintenance, and security costs (Park, Kwon, & Del Pobil, 2016). Maintenance costs are

limited, but investment costs are high, and a reasonable return time is only feasible when sports facilities are used intensively and for high-level competitions (Fantozzi, Leccese, Salvadori, Rocca, & Garofalo, 2016).

Currently, local government budgets in Korea are being used to maintain facilities and make them profitable (Park, & Kwon, 2018). Golf clubs have transitioned from a state of economic growth prior to the COVID-19 pandemic to facing various challenges, such as a lack of tourism, increased costs, and the need to install new safety and maintenance protocols (Macías, Bonal, León-Quismondo, Iván-Baragaño, del Arco, Burillo, & Fernández-Luna, 2023). Bekken, Schimenti, Soldat & Rossi (2021) found that changes in the risk associated with pesticides on golf courses were linked to economic factors, such as maintenance budgets, and could be effectively reduced by decreasing the use of pesticides on fairways and opting for products with lower risks.

Studies on recreational facilities also used a regional travel cost model to estimate the recreational use value of hiking in Belenden Ker National Park, Australia, similar to other studies assessing recreational benefits. These estimates can be used by park management when considering introducing a user fee system. Additionally, they may be important in decisions about resource allocation for maintenance or upgrades of tracks and facilities (Nillesen, Wesseler, & Cook, 2005). Westerbeek (2000) tested the hypothesis that maximizing the revenue of sports facility tenants depends on the facility's geographical location (distribution location). Bekken, Schimenti, Soldat & Rossi (2021) researched changes in the risks associated with pesticides on golf courses related to economic factors, such as maintenance budgets, which could be effectively reduced by minimizing pesticide use on fairways and choosing less hazardous products.

In summary, maintenance costs are an essential component of the total lifecycle costs of sports facilities. The ability to accurately predict maintenance costs provides a crucial management tool during the maintenance management stage of sports facilities. This can help sports facility maintenance managers optimize resource allocation, improve maintenance plans, and ensure the functionality and safety of the facilities are maintained. Additionally, managing maintenance costs not only ensures the normal operation of the facilities but also profoundly affects their economic sustainability.

4.5 Sustainable Development and Artificial Intelligence

Zhu, Gao, Zhu, & Zhang (2020) aim to explore the issues of post-event utilization of large sports venues within the context of sustainable development, creating an evaluation system for the post-event use of these venues that includes comprehensive performance, service level, environmental performance, economic performance, and venue maintenance. Stinnett & Gibson (2016) focus on assessing the perceived benefits and challenges of implementing sustainable initiatives within university recreational sports facilities, with the identification of perceived benefits helping facility managers and executives find reasons to pursue sustainable facility design and operation.

Managing sustainability in large infrastructure is a formidable task (Jiao, Du, Liu, Liu, Sun, & Shi, 2023). To improve this, scholars have proposed a sustainable digital twin (DT) model for the operation and maintenance of architectural infrastructure, called SDTOM-BI. This proposed method allows for the identification of critical factors during use, enabling sustainable operation and maintenance of building infrastructure. Liu, An & Osmani (2023) aim to explore the integration of BIM, sports, and facilities by revealing the current state of

research in this area, identifying development paths and emerging fields, and emphasizing the application of deep learning, the Internet of Things, and immersive experience technologies as current hot topics. This could provide more innovative breakthroughs for the sustainable development of BIM integration with sports facilities.

Marion & Wimpey (2017) have developed a new trail sustainability rating tool, which can be used to assess or improve the sustainability of existing or new trails. Fischer, Helfricht & Stocker-Waldhuber (2016) primarily study the sustainable maintenance of infrastructure in glacier ski resorts. Researchers aim to determine best practices for fitness center management to enhance customer engagement and achieve long-term business stability and sustainability (León-Quismondo, García-Unanue, & Burillo, 2020). The strategies used can help managers of these and other sports facilities design sustainable management plans to address potential future health or economic crises.

Tang, Xu & Xiao (2024) studied large event venues, finding that the overall sustainability of these venues is at a moderate level with relatively higher ecological sustainability. Over time, the sustainability of the venues has improved, while the economic dimension of sustainability has declined. They also identified indicators that hinder the sustainability of Olympic venues and proposed strategies to enhance venue sustainability from ecological, social, and economic dimensions, enriching the understanding of Olympic legacies and sustainable venues, providing theoretical significance for venue sustainability assessments, and practical implications for the construction and utilization of sports facilities as sustainable urban infrastructure.

Boussabaine (2001) analyzed energy operational costs using statistical techniques and artificial intelligence methods, developing three types of modeling: linear/non-linear regression, neural networks, and neuro-fuzzy to predict energy costs. Bouabdallaoui, Lafhaj, Yim, Ducoulombier & Bennadji (2021) collected data using IoT devices and building automation systems (BAS) from various HVAC units, then used deep learning models to predict failures.

In summary, the importance of sustainable development and artificial intelligence in facility maintenance management cannot be overlooked. Their integration not only aids in achieving long-term stability and efficient operation of facilities but also promotes the protection of the global ecological environment and the harmonious development of socio-economics. In future research and practice, further integration of these aspects will become a crucial topic for enhancing facility management levels.

4.6 Research Frontiers Analysis

Mutation monitoring refers to the analysis of sudden emergence of a research hotspot within a certain year or years. Scholars in the field of sports facility maintenance management also use this method to analyze research frontiers (see Figure 7). The research frontiers in sports facility maintenance management are rapidly evolving, strongly influenced by global health trends, technological innovations, and sustainable development policies.

Sustainable Development and Environmental Management: As environmental awareness increases, the design and construction of sports facilities are increasingly utilizing sustainable materials and technologies. Research will focus on reducing the energy consumption and carbon emissions during the maintenance of sports facilities, achieved through more effective energy management systems and optimized facility operations and maintenance.

Technology Integration and Artificial Intelligence: Applications of the Internet of Things (IoT) involve using sensors and smart devices to monitor energy usage, air quality, and equipment status of facilities, enabling real-time, data-driven maintenance decisions to provide more personalized services and improve overall facility efficiency. Artificial intelligence is used for predictive maintenance and energy management optimization to enhance user satisfaction. Advanced safety management systems are developed to prevent and respond to emergencies, such as fires, natural disasters, and other safety threats.

Policy Research and Interdisciplinary Studies: Interdisciplinary collaboration among sports science, environmental science, and engineering technology is conducted to address complex issues in sports facility maintenance management comprehensively. Meanwhile, research on policies and regulations affecting sports facility maintenance management, especially new regulations in the fields of sustainable development and public health, is undertaken.

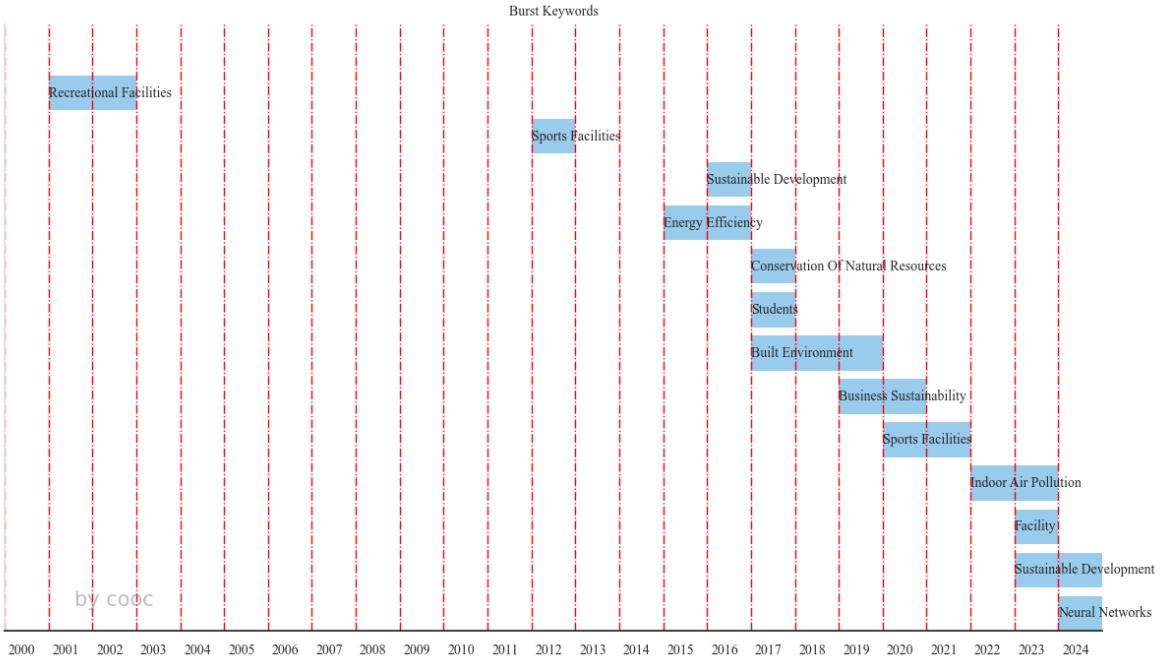

Figure 7: Mutation monitoring of sports facility maintenance management research papers

5. Conclusion

The maintenance management of sports facilities is crucial as it ensures the safety and functionality of these facilities. Effective maintenance can prevent accidents and injuries by addressing potential hazards, thereby protecting users. Additionally, well-maintained sports facilities contribute to extending the lifespan of the infrastructure, thereby reducing long-term costs associated with repairs and replacements.

A comprehensive literature review in this study is highly necessary as it helps to synthesize existing research findings, identify best practices, and promote continuous improvement in sports facilities management practices. The research found that the hotspots in the field of sports facilities maintenance management mainly focus on five groups of research themes: "Lifecycle and Facilities Management," "Project Management and Preventive Maintenance," "Risk Management, Building Environment, and Energy Efficiency," "Cost," and "Sustainable Development and Artificial Intelligence."

The role of literature reviews in the field of sports facilities maintenance management extends beyond academic research. It also provides theoretical research-based feasible suggestions for policy-making, guiding the development of standards and regulations for sports facilities maintenance management. It helps facility managers adopt the latest and most effective practices, ensuring that sports facilities remain safe and functional. In future research, scholars will increasingly rely on technological innovations and data analysis to adapt to the new trends in the ever-evolving field of sports facilities maintenance management.

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References

Baycan-Levent, T., & Nijkamp, P. (2009). Planning and management of urban green spaces in Europe: Comparative analysis. *Journal of Urban Planning and Development*, *135*(1), 1-12.

Bekken, M. A., Schimenti, C. S., Soldat, D. J., & Rossi, F. S. (2021). A novel framework for estimating and analyzing pesticide risk on golf courses. *Science of the Total Environment*, *783*, 146840.

Bezold, C. P., Stark, J. H., Rundle, A., Konty, K., Day, S. E., Quinn, J., Neckerman, K., & Roux, A. V. D. (2017). Relationship between recreational resources in the school neighborhood and changes in fitness in New York City public school students. *Journal of urban health*, *94*, 20-29.

Bouabdallaoui, Y., Lafhaj, Z., Yim, P., Ducoulombier, L., & Bennadji, B. (2021). Predictive maintenance in building facilities: A machine learning-based approach. *Sensors*, *21*(4), 1044.

Boussabaine, A. H. (2001). A comparative approach for modelling the cost of energy in sport facilities. *Facilities*, *19*(5/6), 194-203.

Boussabaine, A. H., & Kirkham, R. J. (2004). Simulation of maintenance costs in UK local authority sport centres. *Construction Management and Economics*, *22*(10), 1011-1020.

Bralewska, K., Rogula-Kozłowska, W., & Bralewski, A. (2022). Indoor air quality in sports center: Assessment of gaseous pollutants. *Building and Environment*, *208*, 108589.

Brinkoe, R., & Nielsen, S. B. (2018). Multiplying the use of space and what it implies in practice: A cross-case analysis. *Journal of Facilities Management*, *16*(2), 197-216.

Bueno, B. L., Mazzei, L. C., Scaglia, A. J., & Almeida, T. C. D. (2020). Geographic Information System as an aid instrument for public policies and management of sports facilities and programs. *Motriz: Revista de Educação Física*, *26*(02), e10200016.

de Sousa Neto, E. D., Berenguer, R. A., Barreto, L., e Silva, A. J. D. C., Lins, C. M. M. S., & Monteiro, E. C. B. (2015). Analysis of Pathological Manifestations and Structural Recovery of the Sports Gymnasium for the 2016 Olympic Games in Brazil. EJGE, 20(26), 13023-13035.

Fantozzi, F., Leccese, F., Salvadori, G., Rocca, M., & Garofalo, M. (2016). LED lighting for indoor sports facilities: Can its use be considered as sustainable solution from a techno-economic standpoint?. *Sustainability*, *8*(7), 618.

Fischer, A., Helfricht, K., & Stocker-Waldhuber, M. (2016). Local reduction of decadal glacier thickness loss through mass balance management in ski resorts. *The Cryosphere*, *10*(6), 2941-2952.

Gobikas, M., & Čingienė, V. (2021). Public-private partnership in youth sport delivery: local government perspective. *Journal of Physical Education and Sport*, *21*, 1185-1190.

Güngör, S., & Polat, A. T. (2017). The evaluation of the urban parks in Konya province in terms of quality, sufficiency, maintenance, and growth rate. *Environmental monitoring and assessment*, *189*, 1-11.

Harun, M. T., Salamudin, N., & Hushin, H. F. (2013). Appraisal of the sport facilities maintenance management practices of Malaysian Stadium Corporations. Asian Social Science, 9(12), 93.

Jenkins, G. R., Yuen, H. K., Rose, E. J., Maher, A. I., Gregory, K. C., & Cotton, M. E. (2015). Disparities in quality of park play spaces between two cities with diverse income and race/ethnicity composition: A pilot study. *International journal of environmental research and public health*, *12*(7), 8009-8022.

Jiao, Z., Du, X., Liu, Z., Liu, L., Sun, Z., & Shi, G. (2023). Sustainable Operation and Maintenance Modeling and Application of Building Infrastructures Combined with Digital Twin Framework. *Sensors*, *23*(9), 4182.

Kim, A. A., Sunitiyoso, Y., & Medal, L. A. (2019). Understanding facility management decision making for energy efficiency efforts for buildings at a higher education institution. *Energy and Buildings*, *199*, 197-215.

Lau, E., Hou, H. C., Lai, J. H., Edwards, D., & Chileshe, N. (2021). User-centric analytic approach to evaluate the performance of sports facilities: A study of swimming pools. *Journal of Building Engineering*, *44*, 102951.

León-Quismondo, J., García-Unanue, J., & Burillo, P. (2020). Best practices for fitness center business sustainability: A qualitative vision. *Sustainability*, *12*(12), 5067.

Leung, M. Y., Liang, Q., & Pynoos, J. (2019). The effect of facilities management of common areas on the environment domain of quality of life or older people in private buildings. *Facilities*, *37*(3/4), 234-250.

Leung, M. Y., Yu, J., & Chong, M. L. (2017). Impact of facilities management on the quality of life for the elderly in care and attention homes–Cross-validation by quantitative and qualitative studies. *Indoor and built environment*, *26*(8), 1070-1090.

Li, Y., Yatsuya, H., Hanibuchi, T., Hirakawa, Y., Ota, A., Uemura, M., ... & Aoyama, A. (2018). The association between objective measures of residence and worksite neighborhood environment, and self-reported leisure-time physical activities: The Aichi Workers' Cohort Study. *Preventive medicine reports*, *11*, 282-289.

Liu, Z., An, Z., & Osmani, M. (2023). Integration of building information modeling with sport and facility: current status and future directions. *Buildings*, *13*(7), 1829.

Macías, R., Bonal, J., León-Quismondo, J., Iván-Baragaño, I., del Arco, J., Burillo, P., & Fernández-Luna, Á. (2023). Golf Club Management Challenges towards Sustainability: Opportunities and Innovations during and after the COVID-19 Pandemic: A Qualitative Perspective. *Sustainability*, *15*(18), 13657.

Marinelli, M. (2020). Emergency healthcare facilities: managing design in a post Covid-19 world. *IEEE Engineering management review*, *48*(4), 65-71.

Marion, J. L., & Wimpey, J. (2017). Assessing the influence of sustainable trail design and maintenance on soil loss. *Journal of Environmental Management*, *189*, 46-57.

Nillesen, E., Wesseler, J., & Cook, A. (2005). Estimating the recreational-use value for hiking in Bellenden Ker National Park, Australia. *Environmental Management*, *36*, 311-316.

Omayer, H. M., & Selim, O. (2022). The interaction of BIM And FM through sport projects life cycle (case study: Sailia training site in Qatar). *HBRC Journal*, *18*(1), 31-51.

Park, E., & Kwon, S. J. (2018). Renewable energy systems for sports complexes: A case study. *Proceedings of the Institution of Civil Engineers–Energy*, *171*(2), 49-57.

Park, E., Kwon, S. J., & Del Pobil, A. P. (2016). For a Green Stadium: Economic feasibility of sustainable renewable electricity generation at the Jeju world cup venue. *Sustainability*, *8*(10), 969.

Paterson, E. M. (2013). Briefing: Blue Carpet, Newcastle, UK: public realm design decision making from a user perspective. *Proceedings of the Institution of Civil Engineers-Urban Design and Planning*, *166*(4), 203-205.

Peixoto, C., Pereira, M. D. C., Morais, S., & Slezakova, K. (2023). Assessment of indoor air quality in health clubs: insights into (ultra) fine and coarse particles and gaseous pollutants. *Frontiers in Public Health*, *11*, 1310215.

Ramos, C. A., Viegas, C., Verde, S. C., Wolterbeek, H. T., & Almeida, S. M. (2016). Characterizing the fungal and bacterial microflora and concentrations in fitness centres. *Indoor and Built Environment*, *25*(6), 872-882.

Sharma, R., & Chaudhary, M. (2021). Perceptions of outdoor gymnasiums in National Capital Region, India: creating active environments for health promotion. *Health Promotion International*, *36*(1), 89-100.

Shi, G., Liu, Z., Meng, X., & Wang, Z. (2023). Intelligent Health Monitoring of Cable Network Structures Based on Fusion of Twin Simulation and Sensory Data. *Symmetry*, *15*(2), 425.

Shin, W. S., Jaakson, R., & Kim, E. I. (2001). Benefits-based analysis of visitor use of Sorak-San National Park in Korea. *Environmental Management*, *28*, 413-419.

Stinnett, B., & Gibson, F. (2016). Sustainability and recreational sports facilities: An exploratory study regarding levels of institutional adoption. *Recreational Sports Journal*, *40*(1), 92-104.

Stinnett, B., & Gibson, F. (2016). Sustainable facility development: perceived benefits and challenges. *International Journal of Sustainability in Higher Education*, *17*(5), 601-612.

Tang, C., Xu, S., & Xiao, X. (2024). Transforming “white elephants” into positive legacies for cities: An assessment of the sustainability of winter Olympic venues and its implications. *Sustainable Development*.

Westerbeek, H. M. (2000). Is sponsorship retention dependent on the geographic location of the sports facility?. *Journal of Marketing Communications*, *6*(1), 53-68.

Wu, X., Qin, X., & Zhou, H. (2018). Use of community spaces for sports and fitness–a case study of urban inhabitants in Shenzhen City, China. *International Review for Spatial Planning and Sustainable Development*, *6*(3), 49-62.

Zhu, J. (2015). Analytic Hierarchy Process-based Social Public Sports Facility Utilization and Development Research. *The Open Cybernetics & Systemics Journal*, *9*(1).

Zhu, L. C., Gao, Z., Zhu, J. M., & Zhang, D. (2020). Construction of the evaluation system of sustainable utilization of large stadiums based on the AHP method. *Mathematical Problems in Engineering*, *2020*(1), 9396276.