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BUSINESS OPERATION OF SPORTS FACILITIES IN THE AGE OF DIGITAL TRANSFORMATION AND ARTIFICAL INTELLIGENCE

Abstract: Over the past few decades, sports have increasingly taken on the form of a commercial activity focused on the sports market, profit generation, and the application of supply and demand laws for goods and services. Starting from a psychological and physiological need, through the development of civilization, sport has evolved into a significant social phenomenon and value, with strong political, economic, cultural, and ethical aspects. Today, sport represents a form of entertainment and a way of spending leisure time for a large part of the population. The development of digitalization and artificial intelligence has enabled the professionalization of sports, improving quality, but also raising demands in terms of technical conditions and sports equipment. Managing sports facilities with the help of digitalization and artificial intelligence includes various activities that enable the efficient functioning of the internal structure of each organization oriented toward market goals: human resources management, production processes and materials, marketing, finance, and risk management. The planning and construction of a sports facility must meet principles and functions relating to capital costs, revenue effects, user satisfaction (including visitors), and the facility's functionality for athletes and sports management in the context of training, competition, and recreation.

Keywords: sport, digitalization, artificial intelligence

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Introduction

In recent decades, sports have increasingly acquired the characteristics of a commercial activity oriented toward the sports market, profit realization, and the laws of supply and demand for goods and services. In this way, what once began as a psychological and physiological need has, through civilizational development, transformed into a major societal value and phenomenon, with marked political, economic, cultural, and moral dimensions. Today, sport is a form of leisure and entertainment for a broad segment of society.

The digitalization of sports facilities marks a fundamental shift in how sports are operated, experienced, and accessed. This transformation goes beyond mere technological upgrades; it involves a comprehensive rethinking of the sports ecosystem. By integrating digital solutions, sports facilities can achieve greater efficiency, enhance fan engagement, and create new revenue streams. This essay will explore the various aspects of this digital revolution, examining the key technologies that drive it, the benefits it offers, the challenges it poses, and its future implications. The impact of digitalization is profound and multifaceted, reshaping everything from daily operations to long-term strategic planning within sports organizations. It is a movement that is not just about keeping up with trends but also about innovating and creating new possibilities within the world of sports.

The world of sports, like many other sectors, is experiencing a rapid transformation due to digitalization. This essay aims to explore the impact of digitalization on sports facilities, examining how technology is reshaping the way these spaces are managed, utilized, and experienced by athletes and spectators alike. From advanced booking systems to data-driven training tools and immersive fan experiences, digitalization is revolutionizing the sports landscape.

Digitalization and artificial intelligence have enabled increased quality, but also greater demands regarding technical conditions and equipment. The management and functioning of sports facilities are undergoing major changes due to advances in digitalization and artificial intelligence (AI). Modern sports complexes are no longer merely places for competitions and recreation—they are becoming high-tech centers using digital tools to enhance efficiency, safety, and user experience.

Global statistics indicate that approximately one billion individuals actively participate in sports, whether recreationally or competitively (World Health Organization, 2018; KPMG, 2019). Simultaneously, major sporting events attract a cumulative global audience exceeding two billion people (FIFA, 2018; International Olympic Committee, 2021). The potential consumer base within the sports domain is even more expansive, encompassing nearly two-thirds of the world's population, signifying its vast reach (McKinsey & Company, 2020; Statista, 2023). When viewed as a fundamental human activity – engaging one billion active participants in satisfying anatomical-physiological, motor-functional, and sociocultural needs – the massive audience and consumer base for sports content, amplified significantly by mass media influence, forms the essential foundation for a distinct and rapidly evolving production-economic sector: the modern sports industry (Deloitte, 2023; PwC, 2023; Giulianotti & Robertson, 2009).

Today, modern sports facilities powered by digitalization and AI not only serve sports needs but also fulfill functions related to commerce, entertainment, hospitality, education, and even politics. Modern sports complexes increasingly resemble megamarkets in their appearance, organization, and functionality, featuring strong multifunctionality, developed marketing, and consumer orientation. They often combine

open and enclosed spaces and facilities into a unified whole to achieve maximum functionality and market viability—for both users (audiences and athletes) and owners (governments, shareholders, individuals, or organizations).

Historical Context

Traditionally, sports facilities have relied on manual processes for ticketing, scheduling, maintenance, and communication, operating in a largely analog environment (Scholl & Carlson, 2016; Gillentine & Crow, 2005). However, the advent of digital technologies has paved the way for automation, data analytics, and interconnected systems that streamline operations and create richer experiences for stakeholders (Fried & Mumcu, 2016).

The digitalization of sports facilities began with foundational back-office applications like computerized ticketing systems (e.g., early Ticketron) and basic team/venue information websites in the late 20th century (Santomier, 1983; Hutchins & Rowe, 2012). The early 2000s saw the introduction of more visible fan-facing technologies, including widespread digital signage (HD video boards, ribbon displays) and the emergence of rudimentary fan engagement apps and mobile websites, driven by the dot-com boom and improving venue connectivity (Clavio & Walsh, 2013; Cisco White Papers, early 2000s; IBM "Smarter Stadium" concepts, c. 2008).

The transformative shift accelerated dramatically in the 2010s with the ubiquity of smartphones and IoT (Internet of Things). This era enabled widespread adoption of mobile ticketing (often via QR codes), sophisticated real-time data analytics for teams (performance tracking, opponent scouting), and significantly more interactive fan experiences through feature-rich venue apps (offering in-seat ordering, instant replays, wayfinding) and deep social media integration within the live event environment (Mastromartino & Zhang, 2020; Deloitte Sports Technology Reports, various 2010s; PwC Sports Surveys, various 2010s).

Today, the focus is firmly on creating integrated "smart stadiums". These leverage converged digital infrastructure to manage security (via AI-powered surveillance and access control), optimize energy consumption (through IoT-monitored HVAC and lighting), and deliver hyper-personalized fan experiences (tailored offers, content, navigation) driven by the continuous collection and analysis of data from myriad connected systems and devices (Deloitte, 2023; PwC, 2024; Mastromartino & Zhang, 2020; Intel/Cisco IoT Whitepapers).

The integration of digital technology into sport facilities is not a sudden revolution, but an evolutionary process deeply rooted in broader technological, economic, and societal shifts (Scholl & Carlson, 2016). Understanding its historical context reveals how stadiums and arenas transformed from passive concrete structures into dynamic, interconnected hubs of data and experience, fundamentally altering how sports are consumed, managed, and played (Fried & Mumcu, 2016; Cleland et al., 2021).

The Analog Foundations (Pre-1970s):

Before digitalization, sport facilities operated on purely mechanical and analog systems. Communication relied on telephones, public address systems, and manual scoreboards. Ticketing was paper-based, vulnerable to fraud and logistical headaches. Facility management – lighting, HVAC, security – involved manual controls and reactive maintenance. Fan engagement was largely confined to the live event itself, with limited information flow beyond basic programs and rudimentary statistics. The "experience"

was physical and immediate, but lacked personalization, real-time depth, or remote accessibility (Scholl & Carlson, 2016; Gillentine & Crow, 2005).

The Mainframe Era & Operational Efficiency (1970s - 1980s):

The arrival of mainframe computers and later, minicomputers, marked the first significant digital incursion, primarily focused on back-office operations (Santomier, 1983):

- Ticketing & Finance: Early computerized ticketing systems (like Ticketron) emerged, automating sales and inventory management, reducing errors and fraud (Archival Trade Publications - Amusement Business, 1980s). Payroll and accounting functions migrated from ledgers to databases.
- Basic Data Management: Rosters, scheduling, and rudimentary statistics began to be stored digitally, improving administrative accuracy and reporting (Santomier, 1983).
- Limited Fan-Facing Tech: Electronic scoreboards evolved beyond simple lights, capable of displaying basic scores, time, and simple animations (Archival Trade Publications). Public address systems saw incremental improvements.

The PC Revolution & Connectivity Dawn (Late 1980s - 1990s):

The proliferation of personal computers and Local Area Networks (LANs) decentralized computing power within facilities (Gillentine & Crow, 2005):

- Enhanced Operations: Departments (ticketing, concessions, marketing, operations) gained dedicated PCs, improving departmental efficiency and communication via email and shared drives.
- Point-of-Sale (POS) Systems: Digital cash registers revolutionized concessions and merchandise sales, tracking inventory and sales data in real-time (Gillentine & Crow, 2005).
- Early Broadcast Integration: Facilities upgraded infrastructure (cabling, control rooms) to better support the growing demands of television broadcasts, which themselves were rapidly adopting digital graphics and replay systems (Hutchins & Rowe, 2012).
- The Internet Emerges: The rise of the World Wide Web (mid-1990s) provided the first glimpse of remote digital engagement. Teams launched basic websites offering schedules, rosters, and news, laying the groundwork for future fan interaction beyond the stadium walls (Hutchins & Rowe, 2012).

The Dot-Com Boom, Mobile & Fan Experience Focus (2000s):

This era saw digitalization explode outward, directly impacting the fan experience (Clavio & Walsh, 2013; Cisco White Papers, early 2000s):

- Wi-Fi & Connectivity: The demand for constant connectivity led to the (often initially clunky) rollout of stadium Wi-Fi and Distributed Antenna Systems (DAS) for cellular coverage, enabling fans to share experiences online in real-time (Cisco White Papers, early 2000s; IBM “Smarter Stadium” concepts, c. 2008).
- Enhanced In-Venue Displays: Massive high-definition video boards, ribbon boards, and sophisticated sound systems became standard, delivering replays, stats, interactive content, and targeted advertising.
- Online Ticketing & E-commerce: Platforms like Ticketmaster transitioned

fully online, while team websites evolved into e-commerce hubs for tickets and merchandise.
- Early Mobile: Basic mobile websites and SMS alerts provided scores, gate information, and simple updates. Dedicated team apps began to appear towards the end of the decade (Clavio & Walsh, 2013).
- Data Collection Begins: Loyalty programs and online interactions started generating valuable fan data for marketing purposes (Deloitte Annual Reviews, mid-2000s).

The Smart Stadium Era: Integration, Personalization & Big Data (2010s - Present):

Driven by ubiquitous smartphones, cloud computing, IoT sensors, and big data analytics, facilities transformed into integrated "smart" environments (Mastromartino & Zhang, 2020; Deloitte Sports Technology Trends, various years; PwC Sports Survey, various years):

- Mobile Revolution: Dedicated stadium apps became central hubs for everything: mobile ticketing (QR codes), cashless payments (concessions, merchandise), wayfinding, instant replays, in-seat food ordering, exclusive content, and real-time stats. The smartphone became the remote control for the fan experience (Mastromartino & Zhang, 2020; Deloitte).
- Operational Intelligence (IoT): Networks of sensors monitor everything: crowd density (security/safety), restroom traffic (cleaning schedules), lighting/HVAC usage (energy efficiency), turf conditions (maintenance), and concession stock levels (supply chain optimization) (Intel/Cisco/Huawei IoT Whitepapers; Mastromartino & Zhang, 2020).
- Big Data & Analytics: Vast datasets from ticketing, app usage, POS systems, social media, and IoT sensors are analyzed to understand fan behavior, personalize marketing offers (dynamic pricing, targeted promotions), optimize staffing, predict maintenance needs, and enhance overall operational efficiency (Deloitte; PwC; Fried & Mumcu, 2016).
- Enhanced Broadcast & Immersion: Ultra-high-definition broadcasts, multiple camera angles, augmented reality (AR) graphics, and virtual reality (VR) experiences blur the lines between in-venue and remote viewing. Facilities invest in robust fiber networks to support broadcasters and content creators (Hutchins & Rowe, 2012 - updated context; SportTechie coverage).
- Fan-Centric Personalization: Apps deliver tailored content, food recommendations, and targeted offers based on location within the venue and historical preferences, moving towards a hyper-personalized experience (PwC; Cleland et al., 2021).

Driving Forces & Future Trajectory

This evolution was propelled by:

1. Rising Fan Expectations: Demanding connectivity, convenience, and personalized experiences mirroring their digital lives (PwC Sports Survey).
2. Economic Pressures: Need for new revenue streams (targeted ads, premium digital content, dynamic pricing), operational cost savings, and enhanced fan spending (via frictionless payments) (Deloitte Annual Review of Football Finance).
3. Competitive Advantage: Teams/facilities compete for fans' time and money; digital offerings are a key differentiator (Scholl & Carlson, 2016).

4. Technology Advancements: Moore's Law, mobile proliferation, cloud scalability, and cheaper sensors made complex digital systems feasible (IEEE/ Intel/Cisco White Papers).

Looking ahead, digitalization will deepen with AI-driven operations, predictive maintenance, hyper-personalization via biometrics (consent-based), seamless cashless ecosystems, advanced AR integration for both in-stadium and broadcast experiences, and potentially blockchain for ticketing and fan tokens (Mastromartino & Zhang, 2020; SportTechie). Sustainability goals will also drive smarter energy management systems (Deloitte). The historical journey from manual scoreboards to AI-optimized smart arenas underscores that sport facilities are no longer just venues; they are complex, data-driven platforms where the physical and digital worlds converge to redefine the very nature of the sporting spectacle (Scholl & Carlson, 2016; Beech et al., 2020).

Digital Infrastructure in Modern Sports Facilities

Digitalization in sports encompasses a wide range of technologies and applications. It includes the use of software for facility management, data analytics for performance tracking, digital platforms for event ticketing, and interactive technologies for fan engagement. This shift is driven by several factors. The proliferation of smartphones and the internet has enabled seamless data exchange and real-time communication. Innovations in artificial intelligence (AI), the Internet of Things (IoT), and virtual reality (VR) are creating new possibilities for sports facilities. Modern athletes and fans expect personalized, efficient, and engaging experiences, which digitalization can deliver.

One of the essential prerequisites for conducting sports activities is the existence of an adequate sports facility. Any planned activity of an individual, group, team, club, or sports organization is impossible to organize and implement without a suitable sports facility as an indispensable resource. The human factor and an appropriate facility (or space) enable the realization of athletic potential, i.e., they facilitate the achievement of sports results as the primary goal in sports. However, it is not only their sufficient quantity that matters, but also that these facilities meet prescribed requirements (regarding dimensions, safety, sanitary-hygienic standards, fire safety, technical installations, etc.) to allow sports activities to be conducted within them (Krsmanović, Veličković, 2021).

Modern sports facilities have evolved far beyond concrete and steel; they are now intricate technological ecosystems where seamless digital experiences are paramount. This transformation is underpinned by sophisticated digital infrastructure – the integrated hardware, software, and network systems that enable everything from fan engagement and operational efficiency to athlete performance and venue security. This infrastructure is no longer an add-on; it's the essential foundation defining the modern stadium or arena experience.

The Connectivity Imperative:

At the core lies robust, high-capacity connectivity. Fans expect ubiquitous, high-speed Wi-Fi and cellular service (4G LTE, increasingly 5G) to share experiences on social media, access mobile apps, stream in-stadium content, and utilize cashless systems (Deloitte, 2023 Annual Review of Football Finance). This requires:

1. Dense Fiber Optic Backbones: Miles of fiber provide the massive bandwidth needed to connect all systems and feed data to the cloud.
2. Distributed Antenna Systems (DAS): Essential for reliable cellular coverage throughout dense, often subterranean, structures, handling thousands of

simultaneous connections (Cisco, 2022 - "Stadium Network Infrastructure Design Guide").

3. High-Density Wi-Fi 6/6E: Strategically placed access points handle the enormous data demands of tens of thousands of users, enabling features like instant replay streaming to personal devices (Intel, 2023 - "Wi-Fi 6/6E for High-Density Venues").
4. Private 5G Networks: Emerging as a game-changer, offering ultra-low latency and high reliability for critical operations like security cameras, real-time analytics, and potentially enhanced AR experiences (PwC, 2024 Sports Outlook).

The Internet of Things (IoT) Ecosystem:

Thousands of sensors embedded throughout the facility create a network of real-time data points, driving the "smart" in smart stadiums:

- Operational Efficiency: Sensors monitor crowd density (guiding security and cleaning staff), restroom usage (optimizing cleaning schedules), parking flow, lighting/HVAC consumption (reducing energy costs), and equipment health (predictive maintenance) (Mastromartino & Zhang, 2020).
- Fan Experience & Safety: Environmental sensors (temperature, air quality), wayfinding beacons, and occupancy sensors contribute to comfort and safety management.
- Field/Court Management: Soil moisture, temperature, and light sensors on pitches or under courts ensure optimal playing conditions (IBM Case Study - Wimbledon).

Cloud Computing & Data Analytics:

The sheer volume of data generated – from ticket scans and app usage to concession sales and sensor readings – necessitates cloud platforms for storage, processing, and analysis (AWS, Microsoft Azure, Google Cloud - various sports partnerships).

- Centralized Data Hub: Aggregates data from ticketing systems, POS, Wi-Fi, apps, IoT sensors, and security systems.
- Real-Time Analytics: Powers dynamic pricing, personalized fan offers pushed to apps, optimized staffing levels, and instant operational dashboards.
- AI & Machine Learning: Applied to predict crowd behavior, optimize traffic flow, personalize fan journeys, detect security anomalies, and forecast maintenance needs (Deloitte, 2023 Sports Technology Trends Report).

Integrated Software Platforms & Mobile Apps:

This infrastructure enables powerful software that acts as the central nervous system and the primary fan interface:

- Integrated Venue Management Systems (IVMS): Unified platforms manage everything from access control and security to energy management and maintenance work orders, fed by IoT data.
- Fan-Facing Mobile Apps: Serve as the digital "remote control" for the fan experience: mobile ticketing, cashless payments (wallet integration), in-seat ordering, wayfinding, instant replay, exclusive content, loyalty programs, and personalized notifications (Scholl & Carlson, 2016; PwC, 2024). These apps rely entirely on the underlying network and cloud infrastructure.

Enhanced Broadcast & Media Infrastructure:
Modern facilities are major media production hubs:

- Fiber-Optic Broadcast Cores: High-bandwidth fiber connects broadcast trucks, control rooms, camera positions, and interview areas, supporting ultra-high-definition (4K/8K) and multi-angle feeds.
- IP-Based Production: Transitioning from traditional SDI to IP networks offers greater flexibility and scalability for broadcasters and in-house production teams.
- AR/VR Ready: Infrastructure supports overlaying augmented reality graphics for broadcasts and exploring immersive fan experiences.

Security & Building Management:
Digital infrastructure underpins safety:

- IP Surveillance & Analytics: High-definition cameras with AI-powered analytics (facial recognition, object detection, crowd behavior analysis) enhance security monitoring.
- Integrated Access Control: Digital ticketing linked to turnstiles, access management for staff/vendors, and secure back-of-house operations.
- Building Automation Systems (BAS): Centralized digital control of HVAC, lighting, and power, often integrated with IoT for optimization and emergency response.

Deploying and maintaining this infrastructure is complex and costly, requiring significant upfront investment and ongoing expertise. Cybersecurity is a paramount concern. Future advancements include wider 5G/6G deployment, deeper AI integration for hyper-personalization and automation, broader use of biometrics (for access/payments), advanced sustainability monitoring, and more immersive technologies like sophisticated AR overlays for fans in-stadium.

The digital infrastructure within modern sports facilities is the invisible yet indispensable framework that transforms them from passive venues into dynamic, responsive, and highly personalized environments. It enables seamless fan experiences, optimizes complex operations, creates new revenue streams, enhances safety, and provides valuable data-driven insights. As technology evolves, this infrastructure will continue to be the critical foundation upon which the future of live sports experiences is built, making it a core strategic asset for any modern sports organization (Beech et al., 2020).

Managing Modern Sports Facilities

Managing sports facilities encompasses a wide range of activities concerning the internal functioning of organizations with a market orientation: human resource management, production processes and material use, marketing activities, as well as finance and risk management (Fried & Mumcu, 2016; Masteralexis et al., 2021). Facility managers have a legal obligation (often codified in national safety certification requirements like the UK's Green Guide or equivalent EU directives) to ensure the safety of all participants and visitors to sports events (Frosdick, 2005; Council of Europe, 2016). In recent years, violent and destructive behavior among spectators (such as organized fan groups) has led to serious material damage and even casualties—notably exemplified in Serbia during the 1990s where systemic failures contributed to extreme violence—placing safety and risk management at the center of facility management

concerns (Spaaij, 2006; Djukic, 2012; Giulianotti, 2011).

Area	Traditional Approach	Digitalized Approach
Energy Usage	Fixed schedules, manual adjustments	Smart systems, real-time monitoring, automated adjustments
Staffing	Standardized shifts, manual allocation	Demand-based staffing, data-driven optimization
Maintenance	Reactive maintenance, scheduled checks	Predictive maintenance, IoT sensors, data analytics

Digitalization allows for more precise and efficient facility management through integrated software solutions (often termed Integrated Venue Management Systems - IVMS). Automated systems for booking, electronic payment, and smart sensors for space usage and energy efficiency greatly reduce operational costs and increase service availability (Deloitte, 2023 Sports Tech Report; Mastromartino & Zhang, 2020). Data analytics software helps optimize facility scheduling, and mobile apps provide users with easier access to information and services (Scholl & Carlson, 2016; PwC, 2024 Sports Survey).

The causes of sports-related violence can be viewed through sociological and psychological lenses (Spaaij, 2006; Dunning et al., 2002), but location and architectural design also play a key role (Frosdick, 2005). Traditional stadium stands, which allow unrestricted access to the field (e.g., terraces), are one of the main reasons for limited crowd control. Additional problems arise from facilities lacking numbered seats and regulated entrances (segregation, dedicated turnstiles), which complicates security protocols and increases the risk of incidents (Council of Europe, 2016; Frosdick & Walley, 2008). A key element in crowd management is the "predictability" of potential injuries and incidents, which could jeopardize the safety of attendees and result in legal—or even criminal—liability for management in cases of negligence (Health and Safety Executive (UK), 2013; Toohey & Taylor, 2008).

Artificial intelligence plays a crucial role in enhancing the functionality of sports facilities. AI systems enable real-time data analysis, improve safety protocols through facial recognition and crowd density/behavior analysis, and optimize maintenance through predictive algorithms (Mastromartino & Zhang, 2020; Intel AI Whitepapers, 2023). Smart sensors and AI software can monitor equipment conditions and predict necessary repairs before failures occur, thereby extending infrastructure lifespan and reducing maintenance costs (Deloitte, 2023). Every aspect of an event—from space organization (e.g., ingress/egress routes) to the sports activity itself—is part of the integrated crowd management system, requiring careful planning, responsibility, and continuous improvement to ensure the safety of all involved (Frosdick, 2005; Council of Europe, 2016).

In today's economy, the sports industry holds a highly significant place, both in terms of its size (estimated globally in trillions of dollars) and in the efforts of individual countries to secure a competitive position in the global market (Plunkett Research, 2024; STATISTA, 2024). To properly define and position sports industry products within various market segments, thorough research is required across specific product lines that form a wide range of sports offerings (Mullin et al., 2014). One of the key factors behind

the rapid development of the sports industry is the advancement of knowledge and skills in sports management across various disciplines and the industry itself (Masteralexis et al., 2021; Beech & Chadwick, 2013).

Digital technologies also improve user experience for both visitors and athletes. Virtual and augmented reality enable interactive training and simulations (Hudson et al., 2019), while personalized AI-based apps help users achieve optimal results (PwC, 2024). The introduction of smart cards and digital tickets (often integrated with access control via NFC/RFID) speeds up entry and reduces crowding, improving the overall experience within sports venues (Scholl & Carlson, 2016; Cisco, 2022 Stadium Design Guide).

Digital technologies automate core operations, significantly enhancing efficiency and reducing costs. Online booking systems minimize administrative tasks while improving user accessibility (Mastromartino & Zhang, 2020). Automated access control via smart cards/digital locks enhances security and provides granular usage analytics (Cisco, 2022). IoT sensors enable real-time energy monitoring, optimizing HVAC and lighting consumption (Deloitte, 2023). Predictive maintenance software schedules repairs based on equipment sensor data, preventing failures (Intel AI Whitepapers, 2023).

Data-Driven Training & Performance Enhancement: Athlete development is revolutionized through biometric wearables (tracking heart rate, speed, and workload) and AI-powered analytics software that identifies performance gaps (PwC, 2024). VR simulations create adaptable training environments for skill development and tactical rehearsal (Hudson et al., 2019), providing safe yet realistic scenarios.

Transforming the Spectator Experience: Mobile apps serve as central hubs for ticketing, wayfinding, cashless payments, and personalized content (Scholl & Carlson, 2016). Interactive displays and AR overlays deliver real-time stats and immersive replays (Deloitte, 2023). Social media integration fosters live community engagement (Clavio & Walsh, 2013), while VR broadcasts expand access for remote audiences (Hutchins & Rowe, 2012).

Evolution of the Sports Industry & Management Complexity: The global sports market's growth (valued at ~$500bn+; STATISTA, 2024) has spurred consumer-centric business disciplines focused on evolving preferences shaped by industrialization and digital lifestyles (Beech & Chadwick, 2013; Mullin et al., 2014). Sports facility management requires interdisciplinary expertise—spanning engineering, finance, social sciences, and law—to navigate its dual mandate: social value creation and financial sustainability (Masteralexis et al., 2021; Fried & Mumcu, 2016). Core activities (competitions, training, recreational programs) and user demographics directly dictate organizational structure and resource allocation (Council of Europe, 2016).

Public vs. Private Facility Challenges: Public facilities prioritize community access but face bureaucratic constraints in adopting innovative models (Toohey & Taylor, 2008). Private operators leverage market agility for dynamic event promotion and revenue diversification (e.g., hospitality, retail) but may underprioritize social objectives (Giulianotti, 2011). Both models contend with critical safety obligations, where architectural flaws (e.g., unsegregated terraces) and crowd management failures have historically led to tragedies—notably in 1990s Serbia (Djukic, 2012; Spaaij, 2006).

Sustainability Through Smart Technologies: Digitalization enables environmental stewardship via AI-optimized energy/water systems, reducing waste by 15-30% in leading venues (Trendafilova et al., 2017). Renewable energy integration (solar panels, wind) and smart grid compatibility minimize carbon footprints (Schneider & Sylvester, 2022), while IoT-driven data informs sustainable facility planning (Deloitte, 2023).

Sports facilities must fulfill specific functional criteria to effectively serve athletes, participants, and the community:

1. Training Diversity: Facilities require a mix of enclosed spaces (halls, gyms), open areas (fields, meadows, forest trails), and specialized zones (fitness centers, weight rooms) to support varied training methodologies and adaptability (International Association for Sports and Leisure Facilities [IAKS], n.d.; International Olympic Committee [IOC], 2021).
2. Sport-Specific Design: Infrastructure must be meticulously tailored to the participant capacity and unique technical demands of each sport discipline practiced (Hansen & Gauthier, 1989; IAKS, n.d.).
3. Environmental Location: Sites should avoid proximity to pollution sources while remaining accessible to athlete accommodations or residential areas to minimize environmental health risks and ensure convenience (ISO 20121:2012; Muller et al., 2018).
4. Climatic Suitability: Locations, especially for pre-competition training camps, must offer optimal climatic conditions for both training effectiveness and athlete recovery (IOC, 2021; Reilly & Waterhouse, 2009).

The successful operation of large, multifunctional sports complexes hinges on applying core management functions rigorously: Planning, Organizing, Leading, and Controlling (Robbins & Coulter, 2017; Pedersen & Thibault, 2018). Each hosted event presents an opportunity to enhance public perception of sport, motivate organizing teams, and elevate the facility's overall quality. Consequently, ongoing reconstruction and modernization are imperative to meet the evolving expectations of key stakeholders, including international federations, athletes, spectators, media, and the broader community (Chappelet, 2018; Parent & Smith-Swan, 2013).

Societal progression demands continuous improvement in the design, layout, and equipment of sports centers. Modern facilities must be inherently multifunctional, catering not only to athletic pursuits but also to cultural events and community needs (Schulenkorf et al., 2016; Stevens, 2010). Compliance with ever-rising standards—encompassing programming, service quality, user relations, and organizational efficiency—is non-negotiable (IAKS, n.d.). Rising living standards also redefine essential criteria; for instance, advanced lighting systems are now fundamental, and eco-friendly design utilizing renewable energy sources is increasingly mandated (Berkeley et al., 2017; U.S. Green Building Council [USGBC], n.d. - LEED). Adherence to global construction standards is crucial, prioritizing not only aesthetics but also minimizing environmental impact (ISO 20121:2012; Muller et al., 2018). Meeting the integrated requirements of designers, architects, and planners is a significant challenge but vital for creating healthier, sustainable environments (Chappelet, 2018).

In Serbia, the state of sports infrastructure reflects minimal positive change, hindered by insufficient theoretical development and application of sports science research (Đorđević, 2018; Bogdanović, 2020). Many facilities, constructed decades ago, suffer from neglect and disrepair, resulting in diminished capacity for sporting activities (Ministry of Youth and Sport of Serbia, 2019). Consequently, the quality of services offered—spanning space provision, expertise, safety, and hygiene—has deteriorated significantly compared to past decades (Bogdanović, 2020). Management is often characterized by a lack of professionalism, interest, and motivation to implement necessary changes in areas like modern management practices and marketing (Đorđević, 2018). This leads to widespread dissatisfaction among users (citizens and sports organizations) regarding both service quality and the physical state of the facilities

(Ministry of Youth and Sport of Serbia, 2019).

Modern society's hallmark includes hosting large-scale events (sports or cultural), requiring facilities equipped with advanced spaces, systems, and technology (e.g., sophisticated audio-visual equipment common to both concerts and figure skating competitions) (Parent & Smith-Swan, 2013; Stevens, 2010). Beyond fulfilling cultural, sporting, and sociological needs, the financial viability of these events is paramount (Chappelet, 2018; Preuss, 2013).

Effective sports facility management necessitates expertise across natural, technical, and social sciences, coupled with thorough environmental analysis (Pedersen & Thibault, 2018). Given the prevalent state of outdated infrastructure and equipment, modernization and new construction are urgent priorities globally and critically so in regions like Serbia (IAKS, n.d.; Ministry of Youth and Sport of Serbia, 2019).

Sports facilities include purpose-built or adapted open/enclosed spaces for exercise, training, competition, and recreation, plus essential auxiliary spaces and spectator areas (IAKS, n.d.). This ranges from dedicated structures like swimming pools and stadiums to public parks and natural resources, or multifunctional complexes (sports halls, recreation centers, school facilities). Post-construction, these facilities enter a management system responsible for programming, staffing, revenue generation, cost control, and operational management within the constraints of their design (Pedersen & Thibault, 2018; Stevens, 2010).

Conclusion

The digitalization of sports facilities is revolutionizing the industry, offering numerous benefits such as enhanced operational efficiency, improved fan engagement, and increased revenue generation. While there are challenges to overcome, the future of sports facilities is undoubtedly digital. By leveraging emerging technologies and addressing social and ethical implications, the sports industry can create more sustainable, engaging, and accessible experiences for all.

Digitalization and artificial intelligence are key factors in the modernization of sports facilities. Their application enables more efficient management, improved safety, enhanced user experience, and ecological sustainability. The implementation of modern technologies not only contributes to better functionality of sports facilities but also encourages innovation in sports and recreation, creating smart and sustainable environments for all users.

Planning and building sports facilities should meet certain principles and functions related to capital costs, operational costs (revenues), as well as user and audience satisfaction. It is also necessary to ensure functionality for athletes and sports management, including activities such as exercising, training, competitions, and recreation. Unfortunately, sports facilities in the Balkans are nowhere near the level of those in developed countries. The outdoor spaces often reflect characteristics of socialist realism and are underutilized. These facilities are often inaccessible, and parking areas fail to meet even basic standards. The author of this paper believes that sports facilities need to undergo business restructuring, allowing for the employment of young, educated people with a vision for improvement. Many young people are educated in institutions focused on sports facility management, but only a small percentage of them apply their knowledge in practice.

Universal design is an approach that respects human diversity and promotes inclusion in all aspects of life. Concern for the usability of facilities and spaces represents

a key step in the development of a design that can set certain concepts apart from the competition. This approach, also known as "design for all," is based on recognizing the rights of all individuals—including those with activity limitations—at all levels of society. It provides a high level of health, safety, comfort, and environmental protection. Accessibility is a key element of sustainable built environments, placing the individual at the center of attention.

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