

Review

DOI: <https://doi.org/10.58984/smbic240201325s>

Received: 16.11.2024

Accepted: 17.12.2024

Corresponding author: milan.stankovic@konstantinveliki.edu.rs

INTEGRATION OF SMART TECHNOLOGIES INTO THE INFRASTRUCTURE OF MODERN SPORTS STADIUMS

Milan Stanković¹, Viktorija Misić², Ioanna Siotropou³

Abstract: The paper analyzes the integration of smart technologies into the infrastructure of modern sports stadiums, highlighting their impact on various aspects of the functioning and management of these complex facilities. Smart technologies, such as the Internet of Things (IoT), advanced security systems, energy management, and digital services for visitors, have become key elements in the modernization of sports stadiums. The paper explores how these technologies enhance interaction with visitors, enabling personalized and interactive experiences, as well as improving logistics and security. Additionally, the paper addresses the challenges associated with the implementation of smart technologies, such as high initial costs, technical complexity, the need for specialized personnel, and system maintenance. Case studies of successfully integrated smart technologies in stadiums worldwide are analyzed, emphasizing benefits such as increased energy efficiency, reduced operational costs, and enhanced security protocols. Finally, the paper offers recommendations for future projects, highlighting the need for strategic planning and continuous evaluation of technologies to ensure their maximum potential in the context of sports infrastructure.

Keywords: Smart technologies, sports stadiums, infrastructure, Internet of Things (IoT), energy efficiency

¹ PhD, Full professor, Faculty of Law, Security and Management "Konstantin Veliki", Niš, milan.stankovic@konstantinveliki.edu.rs ; <https://orcid.org/0000-0002-1397-8150>

² PhD, Gen Digital, Prague, Czech Republic, viktorija.misic@gmail.com; <https://orcid.org/0009-0009-6965-1489>

³ Ioanna Siotropou, Omega Training Center EPE, Pireus, Greece,, joans@omaga.gr

Introduction

The sports medicine physician have to be acquainted with the medicolegal components of sports medication insurance (Alomar-Jiménez et al., 2021). It isn't always unusual to have questions concerning legal components even as protecting a sports activities occasion including: healthcare duty, scope of exercise, licensure, legal responsibility, and malpractice. There has been a widespread growth in sports medicine litigation due to the fact 1990. The maximum typically mentioned trouble is the capability warfare of hobby of the team physician. On one aspect is the athlete's health and on the alternative, the group's, coaches', control's interests. However, the sports activities medication health practitioner's precedence have to continually be the athlete's

Smart technologies in the function of modern sports stadium infrastructure represent a significant step towards the transformation of sports facilities into efficient, sustainable, and technologically advanced spaces. In recent decades, sports stadiums have become not just venues for sporting events, but multifunctional arenas that provide complex services for visitors, event organizers, and other users. The integration of smart technologies in stadiums enables improvements in daily operations, resource optimization, enhanced safety, and personalized and interactive services for visitors (Dašić, Ratković, 2022). Technologies such as the Internet of Things (IoT), advanced energy management systems, smart security solutions, digital platforms for improving user experience, and automated logistics systems set new standards in the design and functionality of sports facilities (Dašić, et al., 2023). Smart stadiums offer versatility in event organization, ranging from sports competitions to concerts and conferences, creating adaptable spaces that meet the diverse needs of users. At the same time, these venues become more energy-efficient, reducing operational costs and minimizing environmental impact.

The information society is well-developed and efficient, yet exists within a delicate social and economic system. The key element of this society is information itself. Its quantity and quality are of crucial importance to its users. This has led to a fierce battle for its acquisition, secure storage, and effective extraction. The possession of the right quantity and quality of information can provide a strong advantage in increasing economic benefits, avoiding damage incidents, and creating superiority over competitors or in conflict situations. Information ensures the functioning of social, political, economic, and cultural life. From this perspective, infrastructure is essential to maintaining the operability of societal life. Increasingly, we hear about information as the defining characteristic of the modern world. We are told that we are entering the information age, that a new way of informing prevails, and that we have entered the global information economy.

Many writers even identify the information society of countries like the United States, the United Kingdom, Japan, Germany, and others with a similar lifestyle. Indeed, it seems that information has "today become so important that it is treated as a symbol of the very era in which we live." The interpretation of this symbol has been the source of great controversy. For some, it represents the beginning of a truly professional and caring society, while for others, it signifies tightening control over citizens; for some, it heralds the emergence of a highly educated public with near-universal access to knowledge, while for others, it means the flood of trivialities, sensationalism, and divisive propaganda; for some, it marks the development of the nation-state which has promoted the role of information, while for others, it signifies changes in corporate organization leading to information becoming more critical. However, the main division in thought concerning this interpretation is between those who, on one hand, view it as the emergence of a new type of society, distinct from previous ones. Not all of this is fully satisfied with the term "information society," but if they claim that the current era is special and different, marking a turning point in societal development, then they can be described as its proponents. On the other hand, there are scholars who, while happy to acknowledge the special importance of information in the modern era, argue that the defining characteristic of the present is continuity with the past (Dašić, 2023). We can distinguish between those who support the idea of an information society and those who view informatization as the continuation of pre-established relations. One group could be categorized as those who declare the appearance of a new type of society that has emerged from the old. When reading extensive literature on the information society, many writers deal with underdeveloped definitions of their subject. They often write about specific characteristics of the information society but remain unusually vague about their operational criteria. Eager to conceptualize changes in information, they hastily interpret these changes in terms of different forms of economic production, new forms of social interaction, or innovative production processes.

However, they frequently fail to clearly specify how and why information has become so central today that it establishes a new kind of society. The information society is a term for a society in which the creation, distribution, and manipulation of information has become the most significant economic and cultural activity. The information society contrasts with societies where economic support is primarily industrial or agrarian. The tools of the Information Society are computers and telecommunications, rather than lathes or plows. Policy creators for the G7 (now G8) countries recognized just a few years ago that: Advances in information and communication technologies are changing the way we live: how we work and do business, how we educate our children, study and research, train ourselves, and how we entertain ourselves. The information society does not only affect the way people interact but also requires that traditional organizational structures be more flexible, participatory, and decentralized. The idea

of a global information society can be seen in relation to Marshall McLuhan's prediction that communication media would turn the world into a "global village" (Mussico, N., D. 2021). An information society is one that is characterized by a high level of information awareness in the daily life of most citizens, in most organizations and workplaces; using common or compatible technology for a wide range of personal, social, educational, and business activities, and with the ability to transmit, receive, and exchange digital data quickly between locations regardless of distance.

Methodology

It is important to note that all research on this topic, including this one, must be interdisciplinary, taking into account the guidelines of the Ministry of Information and Telecommunications – Sector for Information Society and Information Security of the Republic of Serbia, as well as the Ministry of Sport and the Ministry of Construction, Transport, and Infrastructure. International frameworks cannot be neglected, and for this purpose, we refer to Cluster 3 – Chapter 10: Information Society and Media, Ministry for European Integration. Lower-level documents show the alignment of bodies such as the Regulatory Body for Electronic Media; Regulatory Agencies for Electronic Communications and Postal Services; the Republic Statistical Office; the Competition Protection Commission; the Institute for Standardization of Serbia; the Republic Secretariat for Legislation; the Republic Geodetic Institute; the Office for Information Technology and E-Government.

Information Society

The Information Age followed the Industrial Age, and in its narrower sense, it refers to the period after 1972, characterized by the speed of information flow, which exceeds the speed of physical movement. Its main feature is the widespread use of information technology, which increases the speed and efficiency of information transmission. In a broader sense, the beginning of the Information Age coincides with the invention of the telegraph in 1837, followed by the development of various devices aimed at processing and transmitting information. It gained full momentum with the advent of personal computers in the 1980s and the establishment of the global network. From an economic perspective, it can be said that it was followed by periods of knowledge economy and the so-called intangible economy, which utilizes knowledge, creativity, and new collaboration opportunities. The digital revolution refers to the consequences of falling prices of digital communication devices and encompasses changes in technology and society. It began in the 1970s with the invention of the microprocessor, while

its peak started in the 1990s with the widespread use of the internet in the private sector. Information and Communication Technology (ICT) encompasses computers, communication equipment, and related services, which study the Information Age. The digital and ICT revolutions occurred simultaneously. In other words, analog devices used for communication and information transmission are undergoing a process of digitization.

This integration of different services (telephony, television, internet, etc.) into a unified digital network is called convergence. The primary driving force of the Information Age is the internet, which enables new forms of communication, business, and learning. The internet is fertile ground for innovation and is fundamentally democratic, as anyone can be a content creator. The characteristics of digital technology include media integrity, media integration, flexible interaction, transactions, tool customization, and the ability to edit text, audio, visual, and video files. Three terms are used to explain the rapid development of ICT: Moore's Law, which states that the power of microchips doubles every 24 months; Metcalfe's Law, which claims that the value of a network increases proportionally with the number of its users; and Internet time, which refers to the fact that the internet enables more intense activities. The consequences of digitization include easier communication between people and computers, the ability to process and store all types of records, and cheaper access to knowledge and information. In the information economy, productivity and competitiveness of factories depend on their ability to create, process, and apply information based on knowledge, relying on the intensive use of information technology. The information economy is global, highly productive, and involves profits derived from the speed of innovation. Other terms related to the same phenomenon, emphasizing different aspects, include knowledge economy, new economy, and network economy. The impact of the ICT revolution is evident in the emergence of e-commerce, i.e., business transactions using electronic communication and digital technology. With the new technological revolution, changes in the labor market have occurred. As a result, there is a growing demand for experts in ICT services, technology, and information economy, as well as providers of intellectual services, such as lawyers, scientists, professors, journalists, etc. Because of all this, continuous learning and improvement will be necessary, facilitated by information technology.

The Information Society is a new type of social formation that is a successor to the industrial society. The evolution of the Information Society is driven by the rapid development of electronics and computer engineering. The impact of information on the development of technology and networks can also be seen in various fields of the individual, society, economy, and culture. These technologies and networks provide a greater range of instruments and services, influencing the behavior and functioning of individuals, society, the economy, and culture. They modify the forms of work, lear-

ning, and entertainment. The subject of the Information Society, its guiding spirit, is not matter and energy, but information.

Due to the fact that information and knowledge have become sciences, it has led to the intensive and continuous use of scientific achievements. This is why it is now called the society of scientific knowledge. Information networks change social relationships, as our modern, fast-paced lifestyle has altered or even reformed familiar social communities such as families, housing, work, and professional orientations. However, new technologies and their products create new communities that, in essence, advance and work on the principle of networks—information networks. More and more new tools are emerging to connect people and groups, increasingly forming networked directions. The Information Society is an economic system built on a global, propagandistic democratic society with an information market trend, with the advantages of science at its core, ensuring the functioning of the information network.

There are government, autonomous, administrative, and defense institutions based on information communication networks, where they can address public affairs, business, and private matters. These can be handled online through information infrastructure, but remotely. Using advanced infocommunication networks in the fields of purchasing, decision-making processes, and transmission, this represents the fastest social progress in the world and history. Information networks enable the state to function resiliently and cheaply. Through information technology, the connection between the individual and the state, as well as between the state and non-governmental organizations, progressively gains a new connotation. Through networks, both individuals and society can directly participate in local, regional, and public affairs and decision-making. In the 1990s, some countries recognized the hidden potential of establishing an information society and took initial steps to align with the expected level of the European Union. The most important stages of this process included the liberalization of telecommunications marketing, the approval of broadband internet access on a wide scale, and the elaboration of strategies determining the policy for creating an information society.

Categorization of Information Infrastructure

As diverse providers, systems (such as transportation, railway, and energy supply systems) are essential to society's daily life, meaning that for an information society, it is necessary to have systems in place to transmit, process, and store information. According to the definition, "Infrastructure is an organization of basic establishments and operations (housing, public works, trade, telecommunications, education, health-care) that ensures the safety of social and socio-economic activities." Information

infrastructures consist of the complexity of such fixed or mobile objects, tools, systems, networks, and their procurements that allow for the acquisition, production, storage, distribution, and use of essential information necessary for the proper functioning of the information society.

The elements of information infrastructure include physical buildings and equipment, as well as experts who can operate them professionally as allies. Information infrastructure is an organized, functional, professional, and efficient operation of society. Within the information infrastructure, there are infrastructure groups with different designations. Depending on their usage, we distinguish them into global information infrastructure, national information infrastructure, and, as part of it, defense information infrastructure. According to their functionality and usage, there are two groups of information infrastructure: functional information infrastructures and supportive information infrastructures. With the designation of the information era and the information society, a global economy has emerged surrounded by a global network. The technological foundations of this global environment are global information infrastructures, which are nothing more than all wired and wireless telecommunications systems, computer networks, remote control systems, navigation systems, and other infocommunication networks that ensure the global collection, storage, processing, and transmission of information. In this global information landscape, the Internet has become an increasingly important source, as it increasingly relies on the rapidly growing electronic commerce and electronic money markets. Countries' organizations connect with global information networks through the use of national information infrastructure. This explains that the information infrastructure is a part of the global information infrastructure. Defense information infrastructures play a key role from the perspective of national security.

These defense information infrastructures cover all instruments that transmit, process information for defense purposes and instruments that store, handle, and visualize information and data. The national defense infrastructure is naturally part of the national information system and, beyond it, has an organic connection with allied defense information systems. The designation of functional information infrastructure is that it physically enables the smooth, uninterrupted functioning of certain information for the functioning of society, that is, the provision of basic information. Among the information infrastructures, the information society has primacy. They guarantee the acquisition, generation, transmission, processing, and use of information.

Functional information infrastructures operate on a large scale, complexly organized networks or systems. Furthermore, innovations in transportation represent a process of developing and implementing new technologies, methods, or approaches to improve efficiency, safety, sustainability, and accessibility of the transport system. These

innovations can include a wide range of changes, from advanced technologies like autonomous vehicles and electrification of transport to the introduction of smart transportation systems that integrate information and communication technologies (ICT) for optimizing traffic management. Innovations can also focus on improving the user experience through digitalization of services, development of new transport models, or implementation of more environmentally friendly solutions in transport.

The goal of innovations in transportation is to create a flexible and dynamic system that can respond to the needs of users and the challenges of modern society, such as urbanization, reducing harmful gas emissions, and improving road safety. Innovations can be technological, organizational, or business in nature and often require collaboration between various sectors and interest groups, including government, industry, academia, and end-users. Essentially, innovations in transportation contribute to the transformation of traditional transport models, enabling more efficient use of resources and creating a more sustainable and accessible transportation system for all participants.

Infrastructure Innovations

Infrastructure innovations include improvements and adaptations in the physical infrastructure of the transportation system. Some examples of these innovations are:

- **Green Corridors:** Roads and highways designed to optimize the flow of environmentally friendly vehicles, focusing on reducing emissions and improving energy efficiency.
- **Smart Highways and Roads:** Infrastructure equipped with sensors, smart lighting, and variable signage that responds to road conditions in real-time (Stanković et al. 2023: 285).
- **Electric Vehicle Charging Infrastructure:** The development of charging station networks that support the fast and efficient use of electric vehicles in rural areas.
- **Smart Bridges and Tunnels:** Installation of sensors and monitoring systems in bridges and tunnels that can track the condition of the structure in real-time and alert to potential problems before they become serious.
- **Climate-Resilient Infrastructure:** The development of roads and bridges designed to withstand extreme weather conditions, such as floods and high temperatures, improving their durability and reducing the need for frequent maintenance.

Stanković, M., Misić, V., Siotropou, L. (2024) *Integration of smart technologies into the infrastructure of modern sport stadium* In: Dašić, D. (ed) *Sporticopedia SMB2024*, Vol 2, No 1, 325-336

These infrastructure innovations help create more efficient, safer, and sustainable transportation systems, promoting economic development and enhancing the quality of life in modern urban and rural areas.

Redefining a Symbol: Bernabéu Is Much More Than a Stadium⁴

The Santiago Bernabéu Stadium, home to Real Madrid, exemplifies cutting-edge architecture and technological innovation, crafted to elevate the experience of visitors and participants alike. Recognized as the Best Stadium in the World at the 2024 World Football Summit (WFS), its transformative renovation was executed through a collaboration between architectural firms L35, GMP, and Ribas & Ribas. Praised for its "groundbreaking features" and "bold vision," the stadium redefines the paradigm of modern sports venues.

Architectural and Technological Breakthroughs

The stadium's newly designed exterior shell, featuring a dynamic and adaptive aesthetic, reflects light in a manner that shifts perceptions depending on the viewing angle. Its seamless blend of curved lines and geometric precision creates a commanding presence while delivering both visual elegance and practical functionality, meeting the versatile demands of the venue (Mihic, et al., 2023).

Equipped with a retractable roof, the stadium accommodates events under any weather conditions, ranging from football matches to concerts and corporate gatherings. A standout innovation is the retractable pitch, which can be stored in an underground chamber, preserving its quality and enabling the space to transform for various activities. High-resolution LED screens on the facade enable dynamic presentations of scores, advertisements, and creative displays, complementing the stadium's futuristic appeal. Advanced 360-degree cameras and AI-powered game analysis systems enhance broadcast quality, offering immersive VR experiences to viewers.

Elevated Fan Experience

Fans enjoy unparalleled comfort with ergonomic seating, additional legroom, heating, and integrated USB charging ports. Interactive screens and mobile apps provide real-time match statistics, opportunities to participate in contests, and simplified navigation within the venue. Improved entry and exit logistics minimize congestion, while

⁴ Welch, A. (2024) Santiago Bernabéu Stadium Building. <https://www.e-architect.com/madrid/santiago-bernabeu-stadium>

advanced wayfinding systems make locating seats, dining options, and retail areas effortless.

Sustainability and Multifunctionality

The Santiago Bernabéu champions environmental responsibility with solar panels and water recycling systems that significantly reduce its ecological footprint. Lush green spaces enhance air quality while contributing to the venue's aesthetic appeal. Automated systems for lighting, climate control, and irrigation further promote sustainability and operational efficiency (Ratković, Dašić, 2018).

Its multifunctional design allows the stadium to host a diverse array of events, from sports competitions to corporate conferences, ensuring both adaptability and financial viability. More than a stadium, the Santiago Bernabéu is a landmark of innovation and progress in sports infrastructure. Its pioneering features set new benchmarks for functionality and fan engagement, solidifying its status as a global icon in the world of sports and entertainment venues.

Conclusion

As previously researched, the crucial development of smart technologies, as key elements in the modernization of sports stadiums, becomes dependent on the phenomenon of locating service systems. The increased focus on business logistics has also contributed to a heightened interest in location decisions, which, according to studies, is thematically primary (Ballou, Masters, 1993) and serves as a foundational framework in this case, institutionalized and structured. It is particularly important how the quality of life decisions is becoming more significant as the workforce decreases, the market becomes more competitive, and the previous work culture within companies becomes a thing of the past. Studies show that for generations after the 20th century, the quality of life decisions often becomes more important than monetary compensation for work.

Building upon the conclusion that transportation infrastructure is not at the top of the list of considerations (Stanković et al., 2023: 295), without a doubt, these factors play a significant role in complex geographic comparisons. Specifically, the assessment should be supplemented regarding each location's ability to meet the transportation needs of the company, especially as more emphasis is placed on technology. Smart technologies, such as the Internet of Things (IoT), advanced security systems, energy management, and digital services for visitors, are becoming key elements in the modernization of sports stadiums.

The renovated Santiago Bernabéu stands as a paradigm of the modern sports stadium, where smart technologies are integrated to enhance every aspect of its functionality

and visitor interaction. Through the implementation of solutions such as the Internet of Things (IoT), advanced security systems, energy-efficient mechanisms, and interactive digital services, the stadium redefines the fan experience and sets new standards for sports infrastructure.

With technical innovations like the retractable roof, retractable pitch, and high-resolution LED facades, Bernabéu not only facilitates the hosting of various events in all weather conditions but also optimizes operational processes. Personalized services, interactive platforms, and improved logistics further enhance visitor satisfaction, while energy management and recycling systems contribute to sustainability and reduced operational costs.

References

1. Ballou, R. H. and Masters, J. M. (1993), Commercial software for location warehouses and other facilities, *Journal of Business Logistics*, Vol.14, No 2.
2. Dašić, D. (2023) Application of delphi method in sports. *Sport, mediji i biznis*-Vol. 9, no 1, 59-71. <https://doi.org/10.58984/smb2301059d>
3. Dašić, D., Ratković, M. (2022) Safety at sports events as a condition for the implementation of marketing potential. In: Dašić, D. (ed) *International Thematic Monograph Security aspects of modern society-implications and possibilities*, Faculty of Law, Security and Management Nis, Serbia Faculty of Security Banja Luka, Belgrade Institute for the Humanities and Social Inquiry (BIHSI), Serbia.495-512.
4. Dašić D., Kostadinović G.,& Alla K. (2023) Market research as a function of marketing development in sports. In: Dašić, D. (ed) *First international scientific conference SPORTICOPEDIA - SMB2023*, Faculty of sport University „Union – Nikola Tesla“Belgrade, SERBIA, 273-284. - DOI: <https://doi.org/10.58984/smbic2301273d>
5. Mussico, N., D. (2021). The Global Village Globalization, rethinking McLuhan in the 21st century, *Comunicación y Hombre* 16(Aldea Global. Globalización):183/203 /December 2021. <https://comunicacionyhombre.com/en/article/the-global-village-globalization-rethinking-mcluhan-in-the-21st-century-4/>
6. Ministarstvo za evropske integracije (2024): Izveštaj o sprovođenju srednjoročnog plana za 2023. godinu / <https://www.mei.gov.rs/srl/dokumenta/izvestaji-o-sprovođenju-srednjorocnih-planova/>
7. Mihic, S. Dašić,D., Bogdanova, M.. (2023) Promotion of sports and fitness throughhealth in Serbia. In: Dašić, D. (ed) *First international scientific conference SPORTICOPEDIA - SMB2023*, Faculty of sport University „Union – Nikola Tesla“ Belgrade, SERBIA, 239 - 250.- DOI: <https://doi.org/10.58984/smbic2301239m>

Stanković, M., Misić, V., Siotropou, L. (2024) Integration of smart technologies into the infrastructure of modern sport stadium In: Dašić, D. (ed) Sporticopedia SMB2024, Vol 2, No 1, 325-336

8. Ratković, M., Dašić, D. (2018), Marketing u sportu, Visoka škola modernog biznisa, Sven, Niš.
9. Stanković et al. (2023). Sports Stadiums and Modern Infrastructure, Dašić, D. (ed.), Sporticopedia – Sport Media and Business 2023, (285 – 299), Belgrade: Faculty of Sport, DOI: <https://doi.org/10.58984/smbic2301285s>
10. Welch, A. (2024) Santiago Bernabéu Stadium Building. <https://www.e-architect.com/madrid/santiago-bernabeu-stadium>