

Investigation of Intelligent Service Mode of Digital Stadiums and Gymnasiums in the Context of Smart Cities

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ABSTRACT

With the innovation of information technology, digital stadiums and gymnasiums are based on independent innovation, information management, and intelligent cultivation and development, which promotes the construction of a new ecology of intelligent sports and also determines the development situation and development mode of traditional sports. In the construction of intelligent service mode of digital stadiums and gymnasiums in the context of smart cities, the management information system, as the application support of stadium information technology, is the key channel to improve the intelligent level of stadiums and gymnasiums. The establishment and promotion of a smart management information system is an inevitable trend for smart stadiums and gymnasiums to complete key technologies, consumer experience, and efficient functional innovation of management methods, which is also an important content of science and technology-enabling stadiums and gymnasiums. This paper proposed the research on intelligent service mode of digital stadiums and gymnasiums under the background of smart cities.

KEYWORDS

Digital Stadium, Intelligent Services, Smart Sports, Sports Venues

INTRODUCTION

A new generation of information technologies like artificial intelligence (AI), the internet of things (IoT), and big data technology have penetrated all aspects surrounding smart sports venues. The application of new technologies can greatly improve the efficiency of comprehensive commands and use. To provide linked services to the wider populace, transport systems combine the IoT with a range of applications, interface designs, or telecommunication systems. A system of interconnected gadgets, or the IoT, exchanges information and communication.

Smart city frameworks (i.e., smart security, smart fire safety, or smart traffic management) and the new generation of information technologies work together to upgrade sports businesses and applications. This effort results in improved user and customer experiences. Smart sports venues use

DOI: 10.4018/IJDWM.322393

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the IoT, big data technology, and in-depth applications to promote smart venues and new infrastructure links. For instance, wearable technology like smart clothing can record biomechanics (i.e., pulse rate or motion) to track progress and monitor health information.

The intelligent construction of sports venues is a growing research interest. Zhang and Breedlove (2021) discussed the need for sports organizations to focus on consumers and emerging technologies. The study found that modern digital technologies (i.e., IoT, data analysis, and wearable devices) can help sports organizations optimize their business and operational capabilities. This, in turn, can enhance brand building, channel integration, service processes, and organizational structure (Zhang & Breedlove, 2021).

It is important to coordinate the venue's atmosphere and tone with its targeted demographic. With the help of computer network technology, Xiao-wei (2020) designed the Sports Culture Center's intelligent system architecture and intelligent interconnected subsystems. This project used information integration and data application networks for resource sharing and upgraded functionality. The results achieved a substantial increase in passenger flow and provided effective ways to make the service of sports and cultural centers more intelligent (Xiao-wei, 2020).

He et al. (2018) explored the operating platform technology group, structured query language server 2005 database, and Microsoft server operating system. Cloud-based technologies and services through Microsoft can be utilized to create and implement smartphone and internet applications. For example, Microsoft Azure provides a range of amenities for developing and delivering large, secure programs. In addition, the research built a university sports network service platform based on Microsoft's operating platform technology. Relevant theories and methods of sports system engineering were adopted in the design and development of the platform, including system functions, information data, target behavior, and other scientific controls (He et al., 2018).

Lei et al. (2019) used methods discussed in the literature, expert interviews, and inductions to analyze the role of intelligent sports on the development of Chinese martial arts. Their research explored innovative methods and measures, aiming to provide reference for the sustainable development of Chinese martial arts (Lei et al., 2019). These studies have certain significance for the sustainable development of sports.

Gao (2019) used investigation, interview, and data consultation to analyze indoor badminton courts in colleges and universities in Gansu Province. The results showed weak innovation of sports venues in Gansu universities. The overall efficiency of indoor badminton courts was not high. It was suggested to develop "Internet + school gymnasium," a public service software, to realize the commercialization, informatization, and scientific and technological intelligent management of the gymnasium with the IoT to improve the management of courts in colleges and universities (Gao, 2019).

Cao (2017) proposed the use of intelligent handheld devices like mobile terminals with servers to improve system functions. Combining connected devices can create intelligent places and things through automated procedures in intelligent dwellings and structures. These can be implemented to increase productivity and optimize processes in several areas, including smart factories and medicine. First, communication protocol can be selected. Communication is then established and the command set is collected. Finally, an intelligent handheld device interface is designed. Combined with the work of a server, the functions of a stadium's original intelligent lighting control system was improved through intelligent handheld devices (Cao, 2017).

Bhatia (2021) provided a novel concept to provide efficient services in the sports field. Based on a comparison and analysis with the latest decision modeling methods, the proposed model enhanced performance values in terms of time delay, classification efficiency, statistical efficiency, correlation analysis, and reliability (Bhatia, 2021).

Through expert interviews, literature, and other methods, Qin (2021) summarized and analyzed the advantages and disadvantages of intelligent sports and traditional sports by combining traditional sports with intelligent education. The research created a more scientific and effective intelligent

education model for colleges and universities to enhance the quality of students' physical education and improve the time and intensity of students' physical fitness (Qin, 2021).

Digital sports exhibition halls use the smart city background to combine the sports industry and information technologies. The development of public sports service projects center on people through new generations of technology, the development of a digital economy and real economy, and the combination of a smart society, new smart city, and smart sports. These efforts promote advanced developments and structural reforms within the sports industry. It also reflects on the practical needs of the sports venue service industry, embracing smart city features like high-quality, diversified, and humanized services.

CONSTRUCTION OF INTELLIGENT SERVICE MODE FOR DIGITAL STADIUMS AND GYMNASIUMS

Smart digital stadiums and gymnasiums should use leading-edge technologies like IoT and cloud computing to enhance their intelligent software systems. Electronic information technologies can collect and transmit information to on-site staff. Service projects can be carefully planned to address customer satisfaction. Applications within cloud computing include e-commerce software, internet data archiving, antivirus implementation, big data analytics, and cloud technologies in education, storage, restoration, and production.

The smart sports industry uses a variety of sensors to achieve an all-round perception of sports behaviors. Sports behavior and sensors include activity trackers, global positioning systems (GPS), accelerometers, and gyroscopes. Cloud computing technology can analyze a large amount of perceptual information, building intelligent responses and intelligent decisions that apply to sports events, national fitness, sports venues, and equipment. Therefore, the digital sports venue delivers important information and builds venue services into their smart service projects.

In addition, the sports industry has been upgraded to a smart industrial chain based on its use of digital stadium and gymnasium platforms (Sha et al., 2018; Yang et al., 2022). Environmentally friendly outcomes within green stadiums include decreased water use, minimized energy use, composting and effective disposal of waste, and the use of environmentally friendly energy sources like wind and solar systems.

The implication of smart stadiums and gymnasiums is impressive. First, the engineering building information entity model designs and implements the stadium engineering projects (rooted in the project lifecycle of sports buildings). The comprehensive method for generating and handling data for an object is known as building information modelling (BIM). By altering the plan, BIM enables designers to foresee future dangers and avoid problems. BIM technologies give property owners more accurate, in-depth building knowledge that can be used to manage structures through cost-effective measures. Increasing project efficiency and streamlining information sharing leads to a more effective building environment. Second, the construction of infrastructure is based on AI, which provides a thorough, in-depth perception of the real-time scene, user behaviors, and hazards. Collaboration is positively impacted by effective communication, work performance, and workplace environment. Third, the visual management of sports and fitness trading customers, venue staff, and the environment can improve service. Fourth, information technology and the basic management theory improve the organizational structure of venue operations, enhancing the efficiency of venue management. The systems approach, situational approach, Model X & Y, and empirical organizational behavior are the most utilized management concepts. Fifth, the purpose of a basic construction of smart stadiums and gymnasiums is to prevent information asymmetry between customers and venues. It also improves service quality, addresses challenges in venue operation, and maintains sustainable development within the environment and economic development of stadiums and gymnasiums (Luo et al., 2019).

A stadium tends to serve as a location for outside events like sports and festivals. It is situated on the ground or a platform. The area may be partially or entirely encircled by a tier-structure for people to observe the action.

Informatization, digitalization, and intellectualization play important roles in the construction of sports venues. Asymmetric information should be considered during the basic informatization phase. Digitization connects and integrates stakeholder resources to establish an accurate and efficient operation mode. Improvements occur during the intellectualization phase (Rigamonti et.al, 2020). The venue's atmosphere and tone should align with the targeted demographic. The construction should also consider the mood and message conveyed to attendees. Customer service technologies can use hardware and software resources to enhance client satisfaction and equip employees with tools to provide improved client care and assistance. A stadium's shape and occupancy level may allow for several thousands of viewers for outside games like soccer, track and field, and baseball. These massive open constructions include seating for fans to watch the competitions. They often feature an eye-catching pattern with a plain center like an oblong or round form that encloses sporting and physical exercise centers with covered facilities for volleyball, wrestling, basketball, or gymnastics. Intelligent products, magnetic induction technologies, the IoT, and various equipment are used to generate solutions for intelligent sports venues. The essence of smart stadiums and gymnasiums is to meet the personalized requirements of customers and generate customized one-stop services. A stream is created by energy generation (or an electromotive force) because of a shifting magnetism. This can occur whenever a conducting is put in a magnetism that is changing (if utilizing an AC source of electricity) or if the wire is continuously flowing in a magnetosphere that is static. It can be said that "ability" is the premise of "intelligence" and "wisdom" is the solidification and improvement of "intelligence." Therefore, smart stadiums and gymnasiums must be upgraded in the planning period. Stadium managers may use intelligent information analyses and statistics to organize their activities in one location with the aid of AI professional activity technology. They should also use information technology to complete smart operations in the operating period, providing customers with efficient and convenient experiences.

In terms of the existing mode of digital sports venues, the focus shifts from site resources to user needs. Service has changed from the simple booking of a venue. Today, it pushes activity information and collects customers' fitness preferences. It has evolved from a single sports venue to a commercial venue with multi-level personalized services. The difference between customer experience and the psychological state of the venue becomes smaller. Overall, the goal of the experience within smart sports venues is to improve service capacities to meet the growing needs of a diversified population.

These factors introduce the concept of public supervision and expanded sports/fitness populations. Specifically, smart sports venues use the IoT and cloud computing technologies to achieve the intellectualization of venue information and services. The dynamic storage and use of data is impacted by the interconnection of venue information and user information. A client database, sometimes known as a customer base or client connection administration (CRM), enables a corporation to track and handle its clients through gathered data. Client information is stored in the company's easily accessible CRM system. Client lists can include addresses, personal details, and e-mail accounts. Specific details may include age, ethnicity, and marital status. The information network resources are then analyzed. The information remodeling services create a hierarchical, three-dimensional service management system to personalize services. In turn, users can receive personalized venue experiences and information on supporting facilities and services. Clients often value these services and feel pleased. Figure 1 is the schematic diagram of the development goal orientation of smart stadiums and gymnasiums.

The service subjects of digital sports venues use the newest generation of information technology and digital media to provide services and support consumers. Their high-level supervision and skills also help other employees grasp the dynamics of the venue. The main service factors of smart sports venues are shown in Figure 2.

The departments and operating organizations that interact with digital sports venues and their service platform operators constitute the supervising body, coordinating and overseeing the construction and services of sports venues. The regulatory body builds an intelligent service platform for stadiums and gymnasiums through various network resources. They use customer retrieval and information feedback to forecast and analyze customer needs. In turn, they can address problems

Figure 1.
Development goal orientation of smart stadiums and gymnasiums

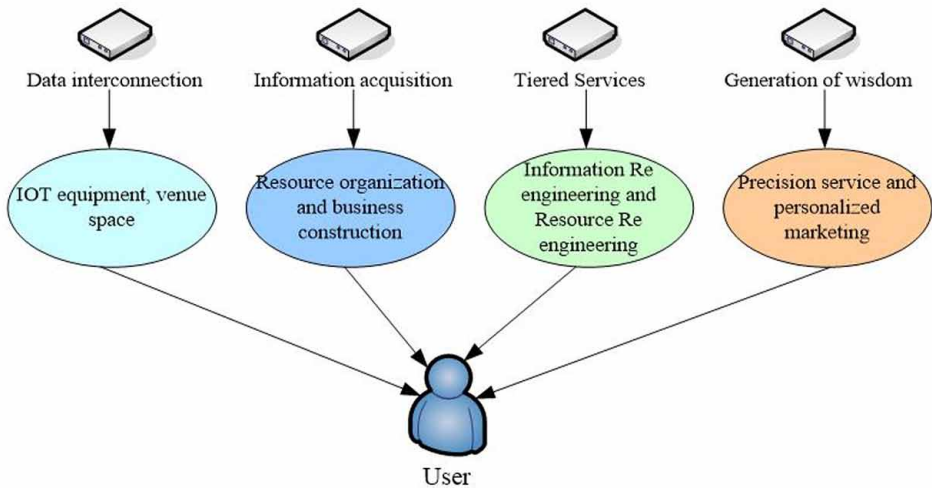
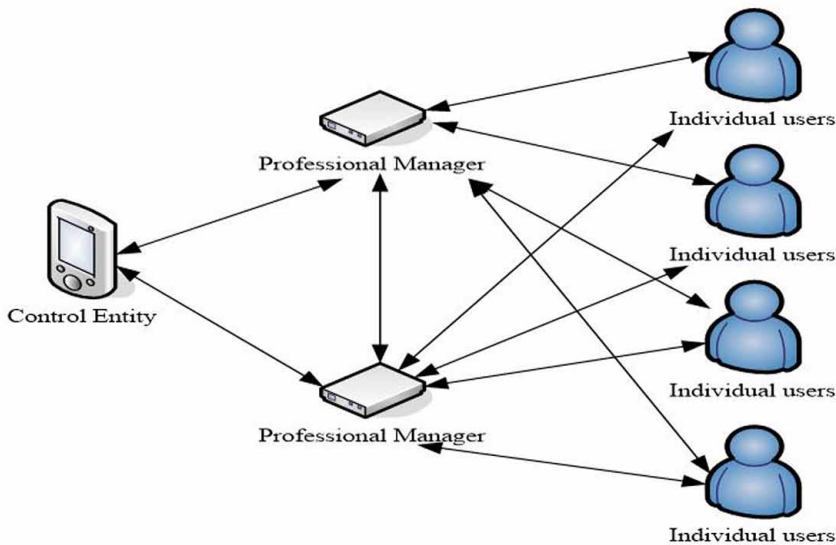


Figure 2.
Service subjects in digital sports venues



that emerge during venue operation, solving challenges, reducing negative impacts, and promoting healthy development. There are several different types of networks, including the campus area network (CAN), system area network (SAN), wireless local area network (WLAN), metropolitan area networks (MAN), local area network (LAN), storage area network, and personal area network (PAN).

Most sports venue employees cannot adapt to the needs of rapid transformation and upgrades within smart venues. Professional managers of smart sports venues, however, differ from general practitioners. These experts use complex capabilities, intelligent systems, and big data mining knowledge to provide professional services (Subramaniaswamy et al., 2018; Wang & Lv, 2019).

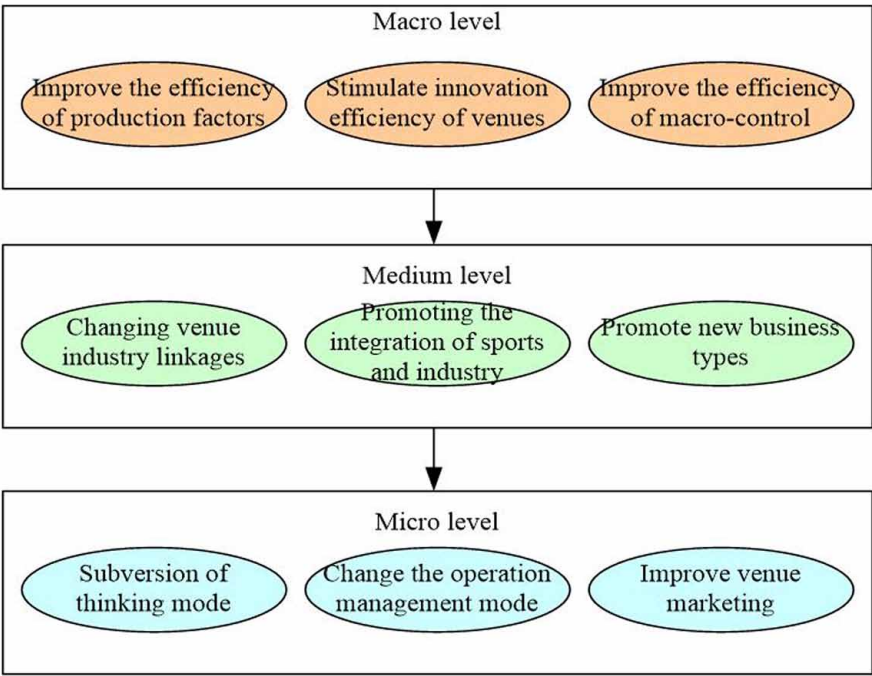
In the era of network information, users play an integral role in the security of smart sports venues. The significant amount of information used on a daily basis can be recorded and stored as data for future browsing. Many tourists and local citizens have become loyal fans of these smart venues. Users produce and transmit information, becoming virtual partners in information dissemination. Teams of individual users engage in the services provided by smart sports venues. Many factors work together to influence users and impact the growth of smart sports venues.

The level of informatization across the country is entering an historical period due to the rapid development of science and technology. New technologies have been widely used in all walks of life. In turn, it has promoted the more refined, systematic management of sports services and advanced the use of intelligent sports in the daily fitness activities of the masses. Users are given humanized, diversified sports services with prospects for the development of advanced sports venues. The construction path of a high-quality development theory mechanism for smart sports venues is shown in Figure 3. Leading-edge technologies and managerial techniques are used to create sports fields that are effective and affordable, improving the satisfaction for both athletes and viewers.

Smart sports venues from a macro perspective aim to improve the efficiency of venue economies of scale, enhance independent innovation, and streamline macroeconomic policies. The middle view impacts smart venues through upgraded service projects that promote industrial integration and new business formats. From the micro perspective, this article analyzes smart venues through thoughtful thinking modes, changes in the business model, and improved venue marketing methods.

The venue operating system is the medium for the operation, publicity, planning, and information exchange of the intelligent stadium information management system. This is the communication between software/hardware and mobile intelligent terminal users. Machine learning (AI), the IoT, wearable technology, mobile apps, sensor technologies, augmented/virtual worlds, big data analytics, and virtual agents accomplish the meta cognition of location data systems. A convenient and reasonable communication

Figure 3.
Theoretical mechanism of the smart stadium system



environment is provided to users according to the application of software and hardware in the program. A good venue operation system plays an important role in improving the level of public supervision, enhancing the management efficiency of competent departments, diversifying the information exchange, innovating the content of sports services, and expanding the venue operation and maintenance platform (Xie, 2021). As shown in Figure 4, the smart stadium operating system is divided into several systems, including the user operating system, enterprise operating system, and venue operating system.

To better enable users to fully experience the services of smart stadiums and gymnasiums, users should have intelligent mobile terminals that support work, daily life, and other aspects on the level of software and hardware. It can ensure that users can browse smart stadiums and choose relevant sports services anytime and anywhere. The enterprise level needs to match the users' software and hardware, which can accept user requests through multiple channels. At the venue level, an intelligent self-service management system should be set up to enjoy intelligent sports services in the venue. Self-service options should also be provided to those who may not be skilled in using intelligent products. At the same time, more professional service staff should be allocated to guide the operation.

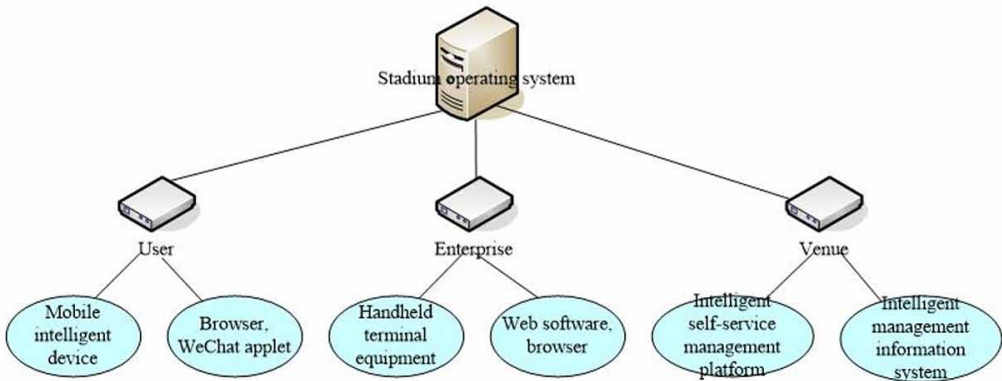
This article proposes research on intelligent service modes of digital stadiums and gymnasiums in the context of a smart city. The formulas involved are as follows:

$$\vec{T}_a = \left\{ (g_m^1, h_m^1), (g_m^2, h_m^2), (g_m^3, h_m^3), \dots, (g_m^7, h_m^7), (g_m^x, h_m^x) \right\} \quad (1)$$

- g_m^x is the x keyword;
- h_m^x is the weight of the x keyword.

$$\text{sim}(m, n) = \frac{\sum_{g \in G_{m,n}} (e_{m,g} - \bar{e}_m)(e_{n,g} - \bar{e}_n)}{\sqrt{\sum_{g \in G_{m,n}} (e_{m,g} - \bar{e}_m)^2} \sqrt{\sum_{g \in G_{m,n}} (e_{n,g} - \bar{e}_n)^2}} \quad (2)$$

Figure 4.
Smart stadium operating system



$G_{m,n}$ is the evaluation of sports by users m and n . $\bar{e}_m$ and $\bar{e}_n$ are the average evaluations of users m and n . $e_{m,g}$ is the score of user m on sports item g . $\text{sim}(m, n)$ is the similarity between users m and n .

$$\text{pred}(m, g) = \bar{e}_m + \frac{\sum_{n \in J} \text{sim}(m, n) \times (e_{n,g} - \bar{e}_n)}{\sum_{n \in J} \text{sim}(m, n)} \quad (3)$$

$\text{pred}(m, g)$ is the score of user m on set J .

$$\text{sim}(O, P) = \frac{\sum_{a=1}^d O_a \times P_a}{\sqrt{\sum_{a=1}^d (O_a)^2} \times \sqrt{\sum_{a=1}^d (P_a)^2}} \quad (4)$$

O_a is the user's preference for the type of sports.

$$\text{thr} = (hr_{\max} - hr_{\text{rest}}) \times ei_{\text{desired}} \quad (5)$$

thr is the training heart rate and $hr_{\max}$ is the maximum exercise heart rate.

$$\text{thr} = (hr_{\max} - hr_{\text{rest}}) \times \rho + ei_{\text{desired}} \quad (6)$$

ρ is the coefficient of motion.

EXPERIMENT ON INTELLIGENT SERVICE MODE OF DIGITAL STADIUM

Surveys can be distributed or promoted through market research organizations, social networks, or a randomized generator. An online survey is an electronic systematic inquiry completed by an intended audience. The duration and structure of an online poll can differ. Often, there are 10 to 25 items in survey responses. Clients might collaborate with an internet survey business like Drive Research to prioritize targets and create inquiries to achieve the study's goals.

Experiments were carried out to better test the effect of the intelligent service mode of digital stadiums and gymnasiums. A questionnaire survey was used to capture and study the attitude of citizens regarding the intelligent construction of stadiums and gymnasiums. A total of 1,000 online questionnaires were distributed. After removing invalid questionnaires, 951 valid questionnaires were recovered (with an effective recovery rate of 95.1%). The relevant experimental results are as follows.

Intelligentization is a key trend in the sustainable development of stadiums and gymnasiums. Many stadium managers realize the necessity of intelligence through the integration of psychological, social, financial, and physical aspects of sustainability. The intellectualization of stadiums and gymnasiums focuses on large- and medium-sized sports venues and large-scale sports events. However, some small- and medium-sized sports venues are also adopting intelligent software and facilities for national fitness.

As shown in Figure 5, digital sports venues plan to carry out intelligent renovations in the future. Eighty-nine percent of venues hope to introduce online booking. Currently, many stadiums and

gymnasiums continue to book on site and via phone. Due to insufficient publicity or habits, online booking is not widely used. Other opportunities for growth include intelligent bathrooms, intelligent physical monitoring, and electronic membership cards.

During the survey, some stadiums and gymnasiums noted that they are actively involved in intelligent renovation. Seventy-two percent of the stadiums and gymnasiums have introduced intelligent changing cabinets and bathrooms. Sixty-five percent of the stadiums and gymnasiums have introduced intelligent physical monitoring to promote more comprehensive sports.

The integration of AI and national fitness can improve the operation of venues and enhance customer satisfaction through modern hardware and services. Factors that impact customer service include prompt responses, customer support, employee knowledge, employees' cheerful disposition, and customized services. Intelligent venue management can also enhance services by reducing the requirement for external stimulation and enhancing safety.

Figure 6 shows the number of times citizens participate in physical exercise every week. The highest amount of exercise per week was three to four times (55.94%). These individuals have dedicated time for physical exercise. The proportion of those who exercise zero to two times and five to six times per week is 19.45% and 17.67%, respectively. The proportion of people who participate in physical exercise more than seven times per week is 6.94%. It can be seen that most citizens have a fixed time for physical exercise. The sports venue experience for citizens also impacts their weekly exercise times. Therefore, it is necessary to enhance the citizens' experience through the intelligent construction of stadiums and gymnasiums.

Figure 7 shows the public's recognition of the stadium's facilities and environment. According to the survey results, most of the citizens are relatively satisfied with the stadium's facilities. The public's recognition of the quality of hardware facilities, types of site facilities, air quality in the venue, sanitary conditions in the venue, greening conditions around the venue, and safety conditions in the venue is 67.59%, 57.64%, 59.45%, 63.76%, 54.37%, and 57.47%, respectively.

Figure 5.
Trends related to digital construction and sports venues

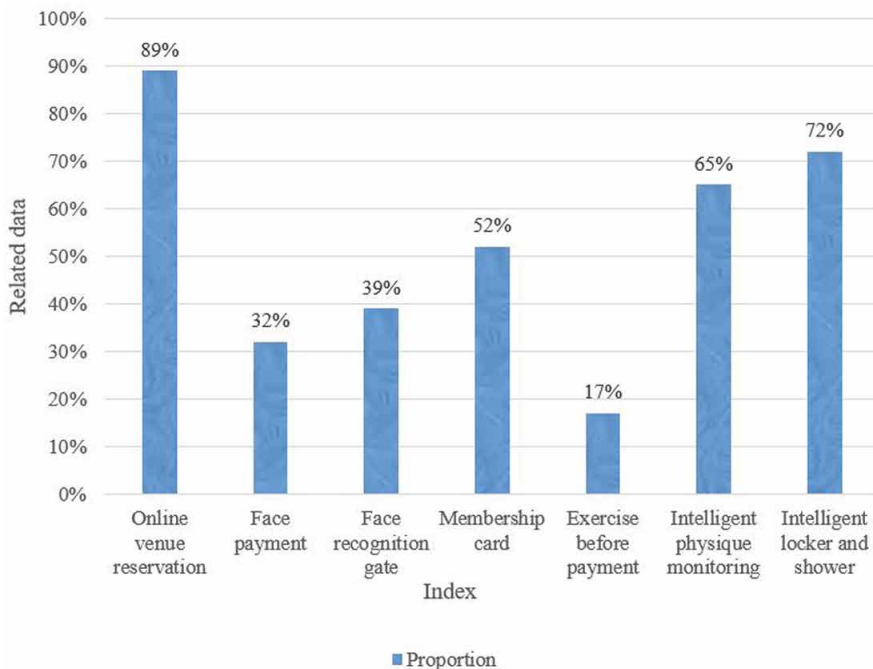


Figure 6.
Physical exercise each week

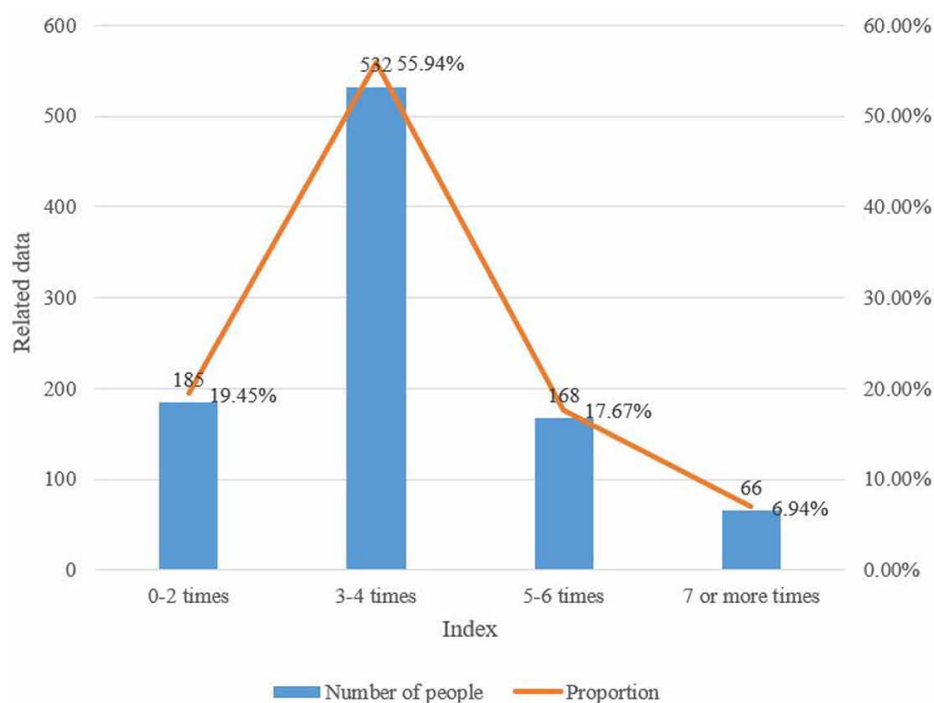
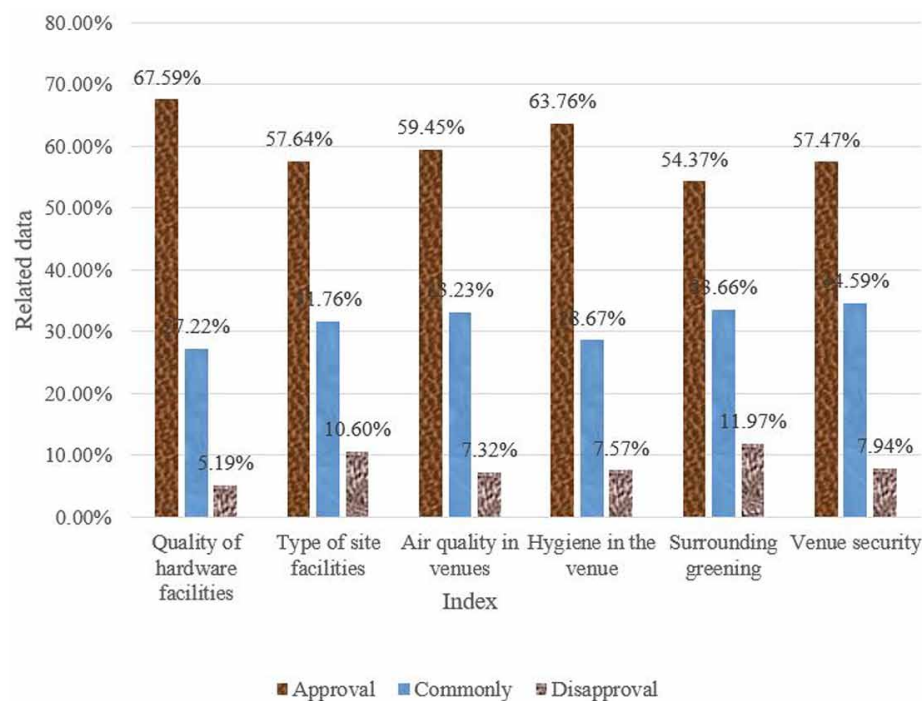


Figure 7.
Public recognition of stadium facilities and environment



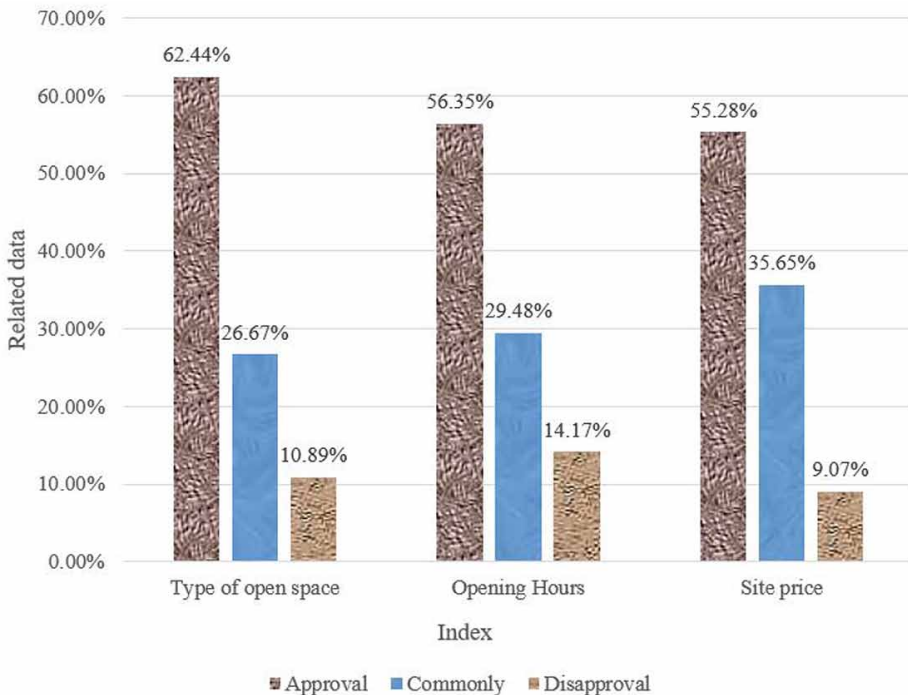
The hardware configuration and facilities are of good quality. The stadiums and gymnasiums have professionals check the facilities, machines, and equipment. They also have regular maintenance and upgrades. Thus, the public's recognition of the quality is good.

The richness of facilities in the venue is key to quality measures. According to the results, 10.6% of the public disapproves of the facilities in the venue. The stadium's air quality and hygiene are important factors surrounding the natural environment of the stadium. These also impact the user's sports experience inside the stadium. Factors include pre-cooled air, purified cooling water, and air flow. Sporting analytics can identify players' interests and objectives through advancements like wristbands that track player speed and motion, gauge blood pressure and pulse rate, or, on a wider scale, track scores or cautions. Stadiums and gymnasiums are crowd intensive venues. Due to the characteristics of some sports, weak natural ventilation may cause dissatisfaction. In addition, 11.97% of the people disapprove of the surrounding greening. Thus, green environment construction around a sports venue cannot be ignored during intelligent construction.

This article investigates the types, duration, and prices of venues open to the public. Figure 8 shows the public's recognition of the opening of sports venues. It shows that 62.44% of the citizens recognize the types of venues open to them; 56.35% and 55.28% of the citizens recognize the venue hours and prices, respectively. It can be seen that most of the sports venues meet the needs of citizens. Only a few of the citizens feel the requirements have not been met.

People feel that sporting facilities should provide resources to stay active all year. Of course, enclosed sports clubs allow players to participate in any weather. Outside areas also offer players court boundaries, fencing, or flat areas for competition. Regarding the duration of the opening of sports venues among the stadiums and gymnasiums under investigation, the hours of operation are relatively long. Thus, there are few people dissatisfied with this matter.

Figure 8.
Public recognition of the opening of sports venues



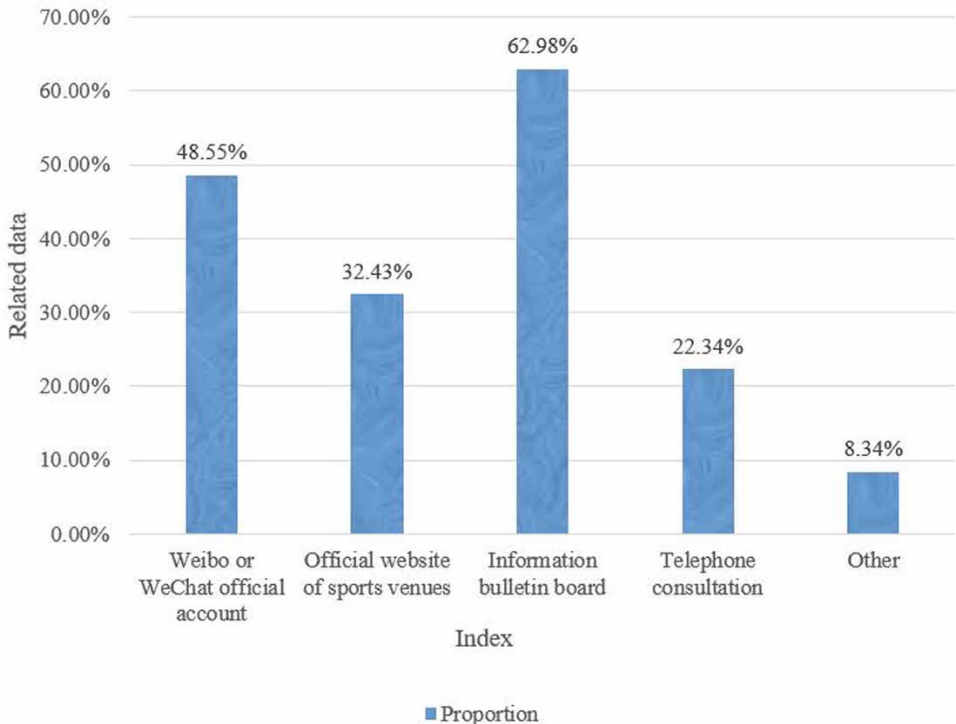
The development of mobile internet technology provides consumers with greater access to stadium information through digital bulletin boards (inside and outside the stadium), hotlines, WeChat public platforms, stadium websites, or third-party software. Traditional information methods like bulletin boards and hotlines continue to be an important channel for people to obtain venue information. Sina Weibo or WeChat public platforms also release basic information for stadiums and gymnasiums. Some stadiums and gymnasiums have small program venue reservation services in the initial stage. Figure 9 shows the most common ways that citizens access consultation information on sports venues.

Only 32.43% of consumers use the official sports venue website or mobile software to book sports venues. Most software is third-party software, which combines the reservation information of multiple sports venues. It is not an independently developed mobile software platform for sports venues. Many managers indicated that sports venues were willing to operate their own system software to provide services like online booking and activity information. However, software production may be cost-prohibitive or requires specialized technicians to operate. In addition, many consumers, especially older users, are accustomed to traditional channels when obtaining venue information. The venue's booking service platform has not received a positive response. For the above reasons, many venues would, therefore, not update the information release channels in a short time.

CONCLUSION

The rapid development of AI technologies provides the sports industry with unprecedented opportunities to proceed with innovative initiatives. However, these advancements can pose a

Figure 9.
Consultation opportunities in sports venues



challenge. Convenient sports venue resource platforms allow people to view a venue's content, participate in its activities, and reserve fitness services. Through AI and big data technology, network operators can handle or adjust operations in a timely manner, incorporate suggestions, and address problems. These features improve efficiency and enhance the public's interest in the sports industry and national fitness.

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