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Research on the Spatial Composite Design Strategy and Practice of University Gymnasiums: A Case Study of the Indoor Gymnasium of Xi'an University of Science and Technology High-Tech College

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Abstract: In the wave of educational reform in recent years, the task of innovating physical education teaching for college students and promoting the all-round development of students' physical and mental health has been placed at the top. This trend demands that the design and renovation of sports venues in major universities must move towards a diversified and integrated path. Sports venues should not only meet the needs of daily physical education teaching but also possess functions such as sports competitions, large-scale gatherings, art exhibitions, and leisure and entertainment. Based on the efficient utilization of the functions of campus sports space, this paper conducts a composite design integration and practical research on the newly-built indoor gymnasium of Xi'an University of Science and Technology High-tech College in Xi'an City, Shaanxi Province.

1. Introduction

This article takes the indoor gymnasium of Xi 'an University of Science and Technology High-tech College as an example to explore the spatial composite design strategies and practices of university gymnasiums. By analyzing the functional integration, spatial flexibility design and operation management mode of this project, this paper studies how to achieve the multi-functional integration of teaching, training, competitions and social services, providing a reference for the intensive design and efficient utilization of gymnasiums in similar universities.

2. Analysis of the Current Situation of Indoor Gymnasiums in Colleges and Universities

2.1. Current Situation of Indoor Gymnasiums in Domestic and Foreign Universities

The sports venues in colleges and universities play a very important role in the sports facilities in our country. According to relevant surveys, the number of gymnasiums in China's higher education institutions accounts for about 3% of the total number of gymnasiums in the country. At present,

there are approximately 850,000 sports venues in China, and university sports venues account for about 69% of the total number of sports venues in the country. Many of these sports venues have reached a relatively high level of facilities. With the expansion of the scale of higher education and the upgrading of campus functions, the construction of indoor gymnasiums in domestic universities has entered a period of rapid development. However, their design and management still face multiple challenges.

In contrast, gymnasiums abroad tend to develop in the direction of indoor comprehensive facilities, integrating various sports events and some facilities for non-sports activities, thus forming gymnasiums with high utilization rates and sufficient facilities. The construction scale of indoor sports facilities is relatively large, and expanding the span of building structures is also the development direction of stadiums abroad. For example, during the 2000 Sydney Olympics, the Royal Australian Agricultural Society Development Pavilion was built in the location where the Olympic venues were concentrated. It served as the venue for the Easter Exhibition and agricultural Exhibition, and during the Olympics, it was used as a press center and a venue for the activities of athletes and journalists.

2.2. Difficulties Faced by the Interior Design of University Gymnasiums

Most gymnasiums in colleges and universities still follow the spatial design logic centered on sports, with fixed spatial layout, pedestrian flow lines and supporting facilities. For instance, the fixed stands, the boundaries of the venue, the limited floor height, the acoustics of the gymnasium, the line of sight, and the space capacity all fail to meet the requirements of supporting activities such as artistic performances and large-scale lectures. Meanwhile, the building structure and form lack variability. Simple renovations are difficult to achieve functional conversion. The average cost of a single renovation exceeds 500,000 yuan and the cycle lasts for 2 to 3 months[1]. According to relevant data, approximately 70% of university gymnasiums in China have difficulty in functional transformation, resulting in an average annual capacity of less than 10 large-scale non-sports events and an average daily idle time of over 12 hours. Meanwhile, the spillover rate of on-campus cultural activity demands is as high as 65%. The contradiction between "idle resources" and "high demand" is extremely prominent[2]. Facing the above problems and difficulties, indoor gymnasiums in colleges and universities should take the path of composite design.

3. Construction of Composite design Theory in Indoor Gymnasium Space

3.1. Concept Definition

Composite design refers to the multiple combinations of space, function and time, enabling a single building to have the ability to support various usage requirements. Its core connotations include the following points: Breaking through the single training and competition functions of traditional indoor sports venues, integrating non-sports activities such as gatherings, exhibitions and large-scale performances, and achieving the composite of spatial functions; The variable structure is achieved by adopting movable partitions, lifting stands and other modular layouts, so that the same space can meet the purpose and function of the conversion space and expand the advantage of space flexibility. In terms of usage management, through time-segmented management, the space utilization rate is optimized to achieve the intersection of usage time for daily teaching and other commercial activities.

3.2. Design Principles

The interior composite design of the school gymnasium should take "intensive and efficient, flexible and variable, diverse and shared" as the core concept and follow the following design principles:

(1) Functional Complexity

The essence of the compound nature of functions is to break the fixed mode dominated by a single function in traditional sports Spaces through the dynamic coupling of space and functions[3]. Through technical means such as movable partitions, multi-functional furniture, and lifting platforms within the space, multiple functions including physical education teaching, event hosting, artistic performances, and exhibition displays are achieved, thereby enhancing the efficiency of space utilization (Table 1). Adhering to the multi-functional hierarchical spatio-temporal collaboration, it achieves the optimization and switching of spatial functions in the time dimension. For instance, the University of Tokyo Gymnasium adopts a time-segmented space usage strategy of daytime teaching, evening club activities, and weekend community opening, enabling a single space to host more than three types of activities on average each day.

Table 1: Implementation Methods of Functional Complexity

Function type	Implementation method	Expected usage scenarios
Physical education teaching and competition	Standard basketball courts and badminton courts, equipped with professional scoring devices	Daily physical education course teaching and on-campus sports competitions
Cultural entertainment	The multi-functional hall is equipped with movable partitions, a lifting stage and professional audio and lighting systems	Campus art evenings, film screenings, academic lectures
Business services	The first floor is equipped with a coffee shop and a sports goods store	Teachers and students take breaks between classes and purchase sports equipment
Leisure communication	Set up open rest areas and reading corners	Student club activities and exchanges and discussions between teachers and students

(2) Spatial Elasticity Principle

The principle of spatial elasticity emphasizes the construction of elastic systems for various functional requirements through the variability of physical space. The principle of spatial elasticity reconstructs the interior design model of gymnasiums, shifting from pursuing spatial certainty to embracing spatial uncertainty. This theory is not only applicable to new projects but also provides a new methodology for venue renovations[4-5]. Adopting modular design thinking to configure variable facilities such as foldable seats and movable stands, a flexible and adjustable indoor space system is constructed to meet the space requirements of activities of different scales and types. For instance, the University of Tokyo Gymnasium has adopted track-type soundproof curtains, which can quickly divide the main venue into three independent teaching areas, increasing the course capacity of each individual area by two times.

(3) Principles of Streamline Optimization

The principle of flow line optimization addresses the interweaving of flow lines, efficiency attenuation and safety hazards in space caused by the superposition of multiple kinetic energies by scientifically planning the movement paths of people, objects and information within the space[6] (Figure 1). The main circulation lines ensure the professionalism of sports activities. For example,

the dedicated passageways for athletes can directly reach the changing rooms and the competition venues, avoiding the intersection of circulation lines between the venues and the audience. Secondary circulation lines are designed with independent entrances and exits and circular routes for non-sports functions (such as exhibitions and commercial activities). The principle of flow line optimization advocates a hierarchical and zoned transportation system within the venue to achieve the separation of flow lines for different user groups within the venue[7].

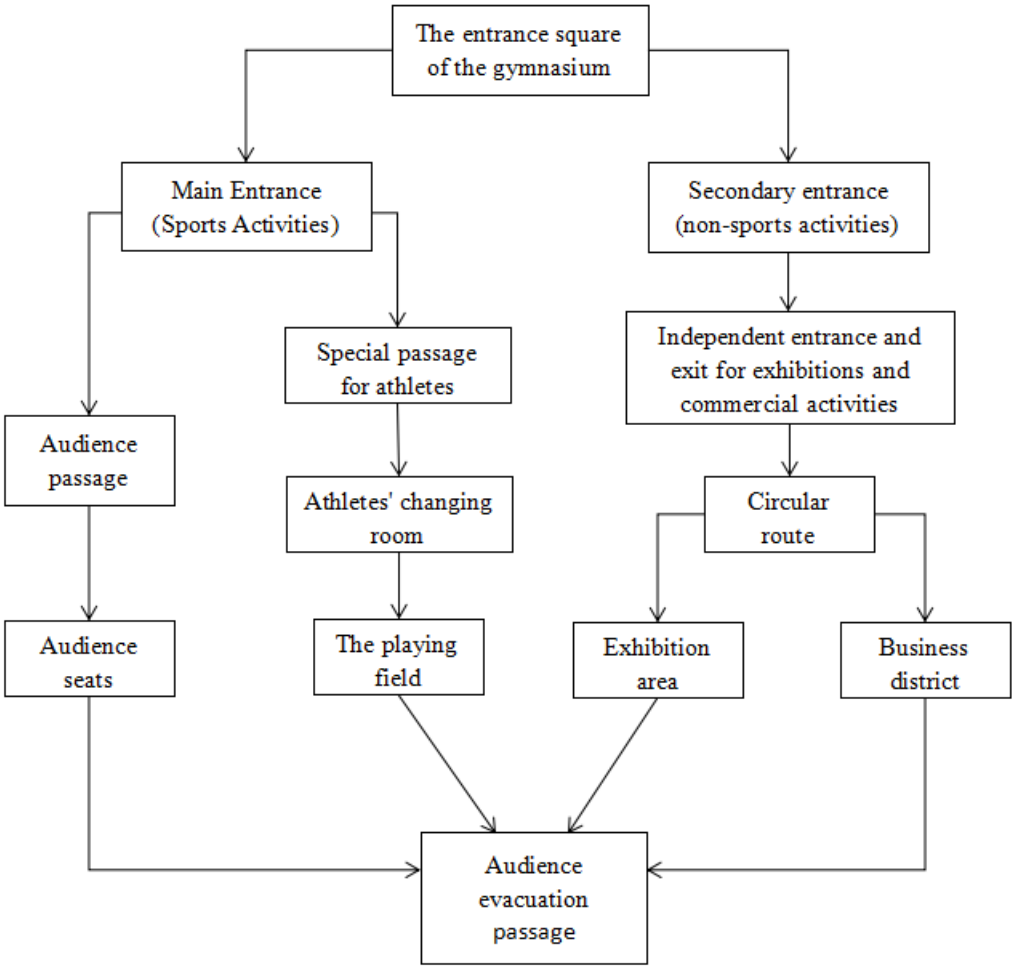

Figure 1 Schematic diagram of the optimization of the gymnasium flow line

(4) Principles of Technology Integration

The principle of technology integration refers to the cross-disciplinary technology integration and systematic collaboration. Its theoretical construction focuses on the following points. The deep integration of variable structure technology and intelligent control technology enables the composite space to break through the static physical structure, combining mechanical variability with digital controllability to achieve the reshaping of the physical space. For instance, the Avery Gymnasium at Stanford University in the United States integrates BIM and the Internet of Things (IoT) platform for intelligent interconnection and control, enabling one-click seat retraction, stage lifting and lowering, and lighting mode switching. This has compressed the traditional 8-hour manual setting of the venue to 90 minutes.

3.3. Influencing Factors

The theoretical construction and practical implementation of the composite design of indoor

gymnasiums are restricted by multiple factors. The core influencing factors can be summarized into the following four categories:

(1) Multi-dimensional Conflicts and Balances of User Demands

The expectations of different groups for the functions of gymnasiums vary. The student group generally pursues convenient Spaces for daily fitness and club activities, and requires small-scale and social scenarios, such as martial arts rooms and dance studios. In terms of school management, it focuses on teaching support and the ability to host major events. Tend to standardize the arena; The public aspect of society expects low-cost opening and commercial services during non-teaching hours, such as swimming training, catering services and other public services for the public.

(2) Campus Planning and the rigid Constraints of Existing Space

The layout of most campuses restricts the freedom of complex design. Most university gymnasiums are located in built-up areas. The expansion requires sacrificing the surrounding green Spaces or the stadium. However, due to insufficient spacing between surrounding buildings and land use restrictions, the development of underground space cannot be implemented[8-9]. There are also some gymnasiums on campuses with a long history that need to take into account the protection of their appearance. For instance, the renovation of some aging gymnasiums on campuses is restricted by the regulations on cultural relics protection and cannot be equipped with external photovoltaic panels.

(3) Trade-off between Technical Feasibility and Economic Cost

Although technological innovation can expand functionality, it also faces the challenge of cost. For instance, hydraulic lifting stages priced at 800 to 1,200 yuan per square meter and intelligent sound insulation systems worth 3 million yuan per gymnasium, such high investments far exceed the investment budgets of traditional university gymnasiums. There are also some risks related to technical adaptation. For instance, a certain university suffered from malfunctions and production halts due to the purchase of foreign-made retractable stands and insufficient arrows in the domestic track system. The maintenance cost of integrated equipment and the equipment itself are also a major challenge to the technical feasibility in integrated design. Maintenance requires mutual coordination and cooperation among professional teams from different departments.

(4) Synergy between Policy Orientation and Operational Mechanism

The sustainability of composite design is determined by the matching degree between the top-level system and the grassroots implementation. Although the "Green Building Evaluation Standard" supports multi-functional design, at present, the approval of infrastructure construction in colleges and universities still leans towards one-time investment as the indicator[10]. The operation of university gymnasiums involves the joint management of multiple departments such as the Sports Department, the Logistics Group, and the university Office. Frequent coordination among these departments inevitably leads to problems such as unclear rights and responsibilities among them, resulting in an uneven distribution of commercial activity profits.

4. Design of the Indoor Gymnasium of Xi 'an University of Science and Technology High-tech College

4.1. Design Concept

Xi 'an University of Science and Technology High-tech College is located in Chang 'an District, Xi 'an City, Shaanxi Province. The newly-built indoor gymnasium on campus serves as the core venue. It is not only a place for students to exercise but also an important space for promoting campus culture and enhancing the sense of belonging among teachers and students. The spatial design concept of the newly-built indoor gymnasium will revolve around its comprehensiveness, flexibility and sustainability, fully considering how to give full play to the multi-functionality of the

space. Through the combination of flexible spatial layout and facility configuration, it ensures that the newly-built indoor gymnasium can meet the needs of different types of activities. Meanwhile, in terms of environmentally friendly materials and energy-saving equipment, the main direction of choice is to enhance the overall utilization efficiency and save energy consumption.

4.2. Actual User Requirements

Based on the actual situation of Xi 'an University of Science and Technology High-tech College, a survey on the functional configuration and satisfaction of the sports functional space in colleges and universities was conducted. Interviews were carried out with students and teachers to understand the specific problems they encountered in the process of sports courses and listen to their suggestions for improvement. The teacher conducted on-site observations and recorded the students' activities and behavioral patterns during the sports process. The teacher is familiar with the physical education teaching curriculum of our school and ensures that the plan meets the actual needs of our school's users. Teachers communicate with the main activity organizing departments of the school to meet the needs of the school in holding various large-scale activities as much as possible.

4.3. Functional Requirements of the Gymnasium

The overall building of the gymnasium is analyzed. The first floor meets the requirements of basketball courts, badminton courts, table tennis courts and daily physical education teaching venues. The second floor is designed for Taekwondo, martial arts, dance and other types of sports classes. The dimensions of the gymnasium construction site are rechecked and the existing spatial layout design is carried out. The rationality of all design circulation lines is grasped. Each classroom is designed with more than two evacuation entrances and exits. The environmental comfort of the gymnasium is investigated, including light, temperature, humidity and noise, etc. In the sports field, it is ensured that the light in each classroom is uniform and bright, the temperature and humidity are controlled, and the noise is isolated. This ensures that each type of physical education teaching or activity does not affect each other during the usage process. Colleges and universities should rationally design the sports atmosphere required for the indoor space of gymnasiums, and unify the wall culture after the interior space design with the overall effect of the plane design.

4.4. The Multi-Functional Design of the Gymnasium in Gaoxin College Is Reflected

The integration means that the configuration within the functional Spaces is complete. Xi 'an University of Science and Technology High-tech College has standard basketball courts, gymnastics courts, badminton courts, table tennis courts and other conventional ball game venues, as well as dance rooms, taekwondo rooms, martial arts rooms and other characteristic sports venues, which can meet the needs of different student groups and support the development of various sports projects on campus. The changing rooms, shower rooms, equipment and facilities rooms, department offices, security and health care rooms and other supporting auxiliary rooms are equipped with a complete physical environment to meet the daily needs of all teachers and students. The basketball court in the gymnasium of Gaoxin College has a certain activity carrying capacity. The venue can be flexibly converted. It can not only be used for daily physical exercise, meeting the requirements of land switching between basketball and badminton courts, but also host large-scale on-campus and off-campus activities, such as cultural performances and academic lectures. In conclusion, the gymnasium is not only the center of sports activities but also the hub of cultural

activities, promoting cultural exchanges, providing students with a platform to showcase themselves, and facilitating the development of various clubs and cultural activities.

4.5. Gymnasium Cultural Construction

The cultural construction of the gymnasium of Xi 'an University of Science and Technology High-tech College can showcase the history, culture and honors of the college through cultural walls, exhibition areas, artworks and other means. By setting up design groups with student participation and collecting students' opinions and suggestions, the cultural construction can be made more representative. Customized real-time event graphic design, closely linked to our school's large-scale events, enables real-time acquisition of relevant event information of our school, and synchronizes with campus large-scale events, enriching our school's campus large-scale events and better promoting the construction of the school's brand culture.

5. Conclusion

In the context where the multi-functional construction of university gymnasias still needs to be improved, the multi-functional design of the new gymnasium of Xi 'an University of Science and Technology High-tech College has greatly enhanced the enthusiasm of college students to participate in sports activities. The rich facilities will encourage more students on campus to take part in exercise and other cultural activities, improve their physical fitness and teamwork ability, and thus enhance the vitality of the campus. Multi-functional activity venues can also provide schools with more opportunities to carry out activities, enhance the campus sports and cultural atmosphere, and strengthen the sense of belonging of teachers and students. At the same time, through an intelligent management system and a comfortable environment design, the user experience of teachers and students is enhanced. Overall, the newly-built indoor gymnasium will become an important infrastructure of Xi 'an University of Science and Technology High-tech College, greatly enriching campus life and creating favorable conditions for the all-round development of students.

References

[1] Chang Y. A study of planning and design for gymnasiums in universities in the new period.Civil Engineering and Urban Planning 2012. 2012: 50-55.

[2] McKay S. Designing Discipline: The Architecture of a Gymnasium. Disciplining Bodies in the Gymnasium. Routledge, 2004: 131-154.

[3] Huang H. Planning Interior and Exterior Spaces of a Modern Gymnasium: Case Study Yubei Stadium. Open House International, 2017, 42(3): 55-60.

[4] Hamid E K, Lafta F A. Mechanisms of environmental adaptation in the design of the interior spaces of gymnasiums. Al-Academy, 2024 (111): 133-152.

[5] Vertinsky P. Locating a 'Sense of Place': Space, Place and Gender in the Gymnasium. Sites of Sport. Routledge, 2004: 8-24.

[6] Collins P, Kuwahara S, Nishimura T, et al. Design and construction of zero-gravity gymnasium. Journal of Aerospace Engineering, 1997, 10(2): 94-98.

[7] Trubacheva S, Onyschuk L. Priority orientations of designing the educational environment of a gymnasium. Education: Modern Discourses, 2019, 2: 55-62.

[8] Shi L, Qiu J, Zhang R, et al. An intelligent optimization method of exercisers' visual comfort assessment in gymnasium. Journal of Building Engineering, 2023, 76: 107135.

[9] Zhdanova I V, Kayasova D S, Kuznetsova A A, et al. Basics of architectural typology of modern fitness centers.IOP Conference Series: Materials Science and Engineering. IOP Publishing, 2020, 775(1): 012063.

[10] Zhan-Yi Z. Ecology-Based Gymnasium Design. Open Cybernetics & Systemics Journal, 2015, 9: 2484-2487.