

MULTI-SCALE SPATIAL OPTIMIZATION RESEARCH ON SMART SERVICE MODELS FOR MASS FITNESS IN RURAL SHAANXI UNDER THE BACKGROUND OF RURAL REVITALIZATION: A PRELIMINARY STUDY

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Abstract: As the rural revitalization and mass fitness national strategies become more deeply integrated, mass fitness services in rural Shaanxi face real challenges such as uneven resource distribution and low levels of smart technology adoption. This study focuses on spatial issues in the smart transformation of rural mass fitness services in Shaanxi. By combining rural revitalization theory, mass fitness theory, smart service theory, and spatial optimization theory, and using methods including literature review, case study, and spatial study, we systematically examine the current situation and multi-scale spatial problems of smart mass fitness services in rural areas across Shaanxi's three major regions: Guanzhong, Northern Shaanxi, and Southern Shaanxi. The research shows that: at the macro level, there is large imbalance in resource distribution, especially smart facilities, between regions and between urban and rural areas; at the meso level, service network coverage at the county and township levels is incomplete with blind spots; at the micro level, village-level facility layouts are poor and smart function use rates are low. In response, we propose multi-scale spatial optimization pathways: at the provincial level, strengthen overall planning, balanced resource distribution, and platform buildion; at the county and township level, build a two-tier smart fitness circle of "township centers - central villages" and improve spatial layout; at the village level, promote demand-oriented precise supply and create practical scenarios; and stress cross-scale cooperation systems. Finally, the study proposes execution strategies including technology enablement, multi-stakeholder working together, content new idea, and talent support, as well as systematic guarantees including policy regulations, funding investment, and operational systems. The aim is to provide theoretical reference and practical guidance for improving the effectiveness of smart mass fitness services in rural Shaanxi and similar regions nationwide.

Keywords: Rural revitalization; Mass fitness; Rural Shaanxi; Multi-scale spatial optimization; Smart services; GIS

1 INTRODUCTION

The rural revitalization plan puts forward new needs for improving the equalization of rural public services. As an important component, mass fitness faces challenges such as weak infrastructure and uneven service supply. Meanwhile, the development of smart services provides new pathways for solving problems like vast rural areas and shortage of professional talent. Rural areas in Guanzhong, Northern Shaanxi, and Southern Shaanxi show large regional differences, and their smart mass fitness services have both universal and unique features. Existing research has shortcomings in systematically solving the "last 1KM" problem of rural fitness services by combining smart service models with multi-scale spatial optimization perspectives, requiring further exploration.

This study aims to build a multi-scale spatial optimization pathway system that adapts to the reality of rural Shaanxi and improves service effectiveness. Core research content includes: ① clarifying theoretical foundations and Shaanxi's current situation; ② analyzing core problems at multiple spatial scales; ③ designing layered optimization pathways at provincial, county-township, and village levels plus cross-scale cooperation systems; ④ proposing execution strategies and guarantee systems. The focus is on identifying bottlenecks at different spatial scales, optimizing cross-scale solution design, and ensuring sustainability[1]. We completely use literature research methods for theoretical tracing and policy review; case study methods to examine practical experience in Shaanxi and advanced regions nationwide; and spatial study methods applying GIS spatial study and accessibility assessment to analyze facility layout features and service blind spots. Following the technical route of "theoretical buildion - empirical diagnosis - pathway design - plan guarantee," we form a logical closed loop.

2 THEORETICAL FOUNDATION AND ANALYSIS OF SHAANXI'S CURRENT SITUATION

2.1 Theoretical Foundation

Under the overall needs of the rural revitalization plan—"thriving businesses, livable environment, social etiquette and civility, effective governance, and prosperity"—and connecting with the "Healthy China 2030" Planning Outline and the Mass Fitness Plan (2021-2025), we set up the logical mainline of "sports empowering rural revitalization": mass

fitness, as an important vehicle for social civility and prosperity, improves the health of rural residents through smart services, which in turn strengthens rural governance effectiveness and promotes deep integration with industry. Based on the theory of equalization of public sports services, we focus on the urban-rural gap and regional imbalance in mass fitness services in rural Shaanxi. Combined with public service product supply theory, we build an infrastructure led by government and supported by enterprises providing smart service model technology, building a supply-demand cooperation system. Using big data to analyze the differentiated fitness needs of rural residents by age, occupation, and region, we introduce precision-matched service theory to solve the problem of supply-demand mismatch.

Based on smart sports theory and digital village buildion needs, with a smart platform as the core, we integrate functions such as fitness guidance, sports events, and health monitoring, and use big data to reach dynamic adjustment of service resources. At the spatial optimization level, macro-level design follows central place theory to build a three-tier smart service hub system at provincial, municipal, and county levels. Guanzhong, relying on its location and economic advantages, focuses on clustered development of smart services; Northern Shaanxi combines ecological management and energy transformation to integrate characteristic fitness scenarios; Southern Shaanxi, based on the ecological advantages of the Qinba Mountains, explores green smart fitness models. All use regional development theory as the theoretical basis for differentiated services, with central cities like Xi'an and Xianyang radiating to counties to balance regional resource distribution. At the meso level, we apply spatial structure theory and combine Shaanxi's "one county, one industry" characteristic industrial layout with fitness-industry integration nodes. At the micro level, we center on villager settlements and cultural squares to improve the spatial accessibility of smart fitness facilities, matching the service radius of familiar social relationships.

Based on rural sociology theory, we analyze the impact of aging and hollowing out on fitness needs in rural Shaanxi. Combined with sustainable development theory, we stress the ecological compatibility and economic practicality of smart service models, ensuring that smart services match the actual carrying capacity of rural areas, such as solar-powered smart venues and recyclable fitness equipment[2]. Finally, we build a four-dimensional theoretical support system of plan-technology-space-society adapted to rural Shaanxi, with the core being information technologies such as the Internet of Things, big data, and mobile internet empowering to improve service efficiency, precision, and practical user experience.

2.2 Diagnosis of Smart Mass Fitness Services in Rural Shaanxi

Shaanxi Province has continued to invest, but overall supply remains inenough and unbalanced. Smart buildion is in the pilot stage, such as in some counties and cities in Guanzhong, with problems of low coverage and inenough use depth. Research shows that in some counties in Southern Shaanxi, village-level smart fitness equipment coverage is less than 20%, and functional use rates are generally low. There are difficulties in precise demand identification, technology use "not fitting local conditions," lack of long-term operational maintenance systems, and inenough enthusiasm for farmer participation[3].

The core of scale spatial problems lies in large imbalances in regional and urban-rural development at different scales. At the macro level, rural fitness resources in Guanzhong, including smart facilities, are superior to Northern and Southern Shaanxi in both density and quality, with urban-rural gaps particularly prominent—the penetration rate of smart services in urban communities is much higher than in rural areas. At the meso level, service networks are incomplete with coverage blind spots. The number of complete smart fitness centers at the township level within counties is scarce; service point layouts in central villages are scattered and functionally weak, leading to poor accessibility in some remote villages, usually exceeding the 30-minute service radius. At the micro level, facility layouts and smart use effectiveness are low: the location of village-level fitness facilities and smart functional equipment deviates from villagers' core daily activity areas, and types are relatively simple; smart functions have high idle rates due to complex operations, unstable networks, or inenough villager awareness[4].

3 MULTI-SCALE SPATIAL OPTIMIZATION PATHWAY DESIGN

3.1 Provincial Level

To reach balanced resource distribution and compensate for the relatively weak development foundation historically formed in Northern and Southern Shaanxi. Southern Shaanxi is constrained by mountainous terrain, making facility buildion and coverage difficult with low service accessibility; Northern Shaanxi has concentrated mining communities where traditional facility types may not meet specific group needs, requiring resource distribution strategies tilted toward Northern and Southern Shaanxi that promote urban-rural integration and regional cooperation. In comparison, Guanzhong has relatively complete facility foundations and service networks, with development focus on quality improvement. Build a unified provincial "one network" platform with unified data standards to enable cross-regional venue reservations and coach sharing. Guanzhong focuses on service upgrades and network density improvement; Northern Shaanxi develops smart fitness considering mining community features; Southern Shaanxi develops small-scale, dispersed smart fitness points adapted to mountainous terrain and cultural features.

3.2 County and Township Level

Using GIS technology, combined with population distribution, transportation networks, and existing facilities, set up a smart node site selection optimization model to minimize service blind spots as much as possible[5]. Build a two-tier smart fitness circle of "township centers - central villages": strengthen the hub function of township-level smart sports complete service centers equipped with relatively complete smart facilities and capable of organizing regional activities; layout standardized smart points in central villages to make sure effective radiation within a 15-minute walking circle, ensuring coordinated layout of sports facilities with other public services; meet residents' daily fitness needs, improve use rates and convenience, and consider accessibility for elderly people, children, and other groups to reach universal service coverage and effectively reduce service blind spots. Use county-level platforms to integrate venue, coach, and activity information for convenient inquiry and reservation. Explore diversified operational models for township center government services.

3.3 Village Level

Based on demand profiles of villagers' age, preferences, agricultural seasons, etc., select appropriate smart facilities and service content, such as providing short, efficient online fitness courses during busy farming seasons that incorporate localized movements like farm tool exercises and field stretching; combine intangible cultural heritage, traditional skills, and other characteristic resources to configure smart facilities. Facilities should be focus on for layout at village committee squares, cultural stations, and other high-traffic gathering points to form convenient service circles. Functional design stresss ease of use, agricultural adaptability, and universal applicability: hardware adopts large fonts, voice interaction, and simplified operation interfaces, and make sures equipment has adaptability to outdoor environments such as dust-proofing, waterproofing, and low-temperature resistance.

Conduct layered operational training, organize smart fitness challenge competitions, local culture digital exhibitions, agricultural information sharing meetings, and other activities; continuously collect feedback through dual channels of online suggestion boxes and offline council meetings, regularly analyze villagers' demand pain points, and dynamically improve facility functions and service content to make sure smart buildion truly benefits people and reaches real results.

3.4 Cross-Scale Coordination Mechanism

Clarify the cross-scale cooperation system through provincial-level overall planning and standard setting, municipal-level cooperation and supervision, county-level resource integration and platform operation, township-level execution, and village-level information feedback and maintenance. At the same time, rely on the provincial "one network" platform to play a hub role, efficiently transmitting cross-level and cross-regional information flows of demand and resource status, policy and dispatch instruction flows, and reservation and guidance service flows, dynamically supporting precise resource distribution, achieving efficient cooperation of responsibilities at all levels, and ensuring execution practicality[6].

4 IMPLEMENTATION STRATEGIES AND GUARANTEE MECHANISMS

4.1 Key Implementation Strategies

Build a multi-scale spatial coordinated planning system. The provincial level focuses on policy guidance and resource cooperation, the municipal level strengthens regional cooperation, with counties as the cooperation scale, clarifying spatial functional positioning at all levels, formulating differentiated execution plans, and townships and villages focusing on facility execution and service delivery, forming a layout framework of scale connection and functional balance. At the same time, promote gradient configuration of smart infrastructure: village level sets up simple smart fitness paths while collecting exercise data; township level builds complete smart fitness centers including integrated physical fitness monitoring, online courses, event reservation functions, etc.; county level set upes a mass fitness smart management platform to reach data interconnection, sharing, and resource scheduling of facilities at different scales[7].

Develop agriculture-adapted smart service content. Combined with the production and life features of rural Shaanxi, design lightweight fitness guidance modules, such as exercise tutorials in local dialects, embed health monitoring functions in agricultural cycles, and link with county-level medical systems to provide remote consultation for sports injuries. Establish multi-stakeholder participation in operational systems. Government leads facility buildion and basic service supply, introduces social forces to operate township-level smart centers, and villagers participate in management, forming a "government + market + villagers" cooperative operation and maintenance model. Strengthen cross-departmental data sharing and security. Open data interfaces between sports, health, agriculture and rural affairs departments, and county-level platforms integrate multiple data to set up farmers' exercise health records[8].

Integrate regional cultural features to improve attractiveness. Excavate traditional sports resources such as Northern Shaanxi yangge and Guanzhong martial arts, integrate intangible cultural heritage into smart fitness courses, set up folk sports VR experience areas in township centers, increase farmer participation enthusiasm, and promote the integration of mass fitness with rural cultural revitalization. Use big data to analyze user behavior and demand changes, set up a multi-scale service effectiveness assessment indicator system, and dynamically adjust facility layouts, service content, and resource distribution strategies every quarter.

4.2 Systematic Guarantee Mechanisms

Issue special policies, technical standards, and smart facility buildion and operation/maintenance norms. Through fiscal guidance, integrate social capital and public welfare donations to set up a diversified investment system and explore sustainable operation models for basic services. In cultural cultivation, strengthen publicity, popularize fitness knowledge, and show effectiveness. Organize experience activities and skill competitions to increase awareness and participation.

5 CONCLUSION

This study identifies the three-scale spatial problems and their correlations in smart mass fitness services in rural Shaanxi: macro-level regional urban-rural imbalance, meso-level incomplete networks, and micro-level low facility effectiveness. It innovatively proposes hierarchical optimization pathways that stress cross-scale cooperation, and clarifies that key strategies and guarantee systems are crucial for execution. By combining smart service models with multi-scale spatial optimization theory, it builds a systematic solution oriented to rural Shaanxi. Its shortcomings are that the research scope focuses on Shaanxi, leading to inenough regions for verifying universality, challenges exist in deep integration and mining of usage behavior data, and the multi-scale spatial optimization model can be continuously improved with more refined data. Future research can expand and deepen regional comparative studies and explore uses of new technologies such as AI.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

FUNDING

This study was supported by:

- 1)the Shaanxi Provincial Sports Bureau 2025 Regular Project "Research on Smart Service Models for Mass Fitness in Rural Shaanxi under the Rural Revitalization Strategy-----Dynamic Planning, Prediction and Assessment of Multi-scale Rural Mass Fitness Spatial Infrastructure in Shaanxi Using ArcGIS Technology" (Project No.: 20250239);
- 2)Shaanxi Provincial Sports Bureau 2025 Regular Project "Research on Long-term Mechanisms for Technology-Driven Mass Fitness under the Background of Rural Revitalization-----Ecological Design and Long-term Management of Rural Revitalization Mass Fitness Facilities Led by Technological Innovation" (Project No.: 20250232).

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